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Descaling by Oxy-Acetylene

In an article in the latest number of the "Iron Age" to reach this country, there is disclosed a system of descaling, cleaning and dehydrating iron and steel by the oxy-acetylene process. It cannot claim to be new, for as long ago as 1928 the method was described by Mr. G. F. Wilson in the following terms: "The operation consists of putting a large-size welding tip in the blowpipe and adjusting the gas pressures so that a somewhat oxidising and blasting flame is produced. By sweeping this flame over successively small areas of the surface to be cleaned, the expansion effect of the intense heat and the blast of the flame is sufficient to loosen and remove the scale which consists largely of burnt sand and metallic oxides and which varies widely as to weight and thickness." The obvious advantages of the system are well brought out by the author, Mr. J. G. Magrath, but he has made no reference to the vitreous enamelling process. One interesting phase he has dealt with, however, is that of surface preparation for painting. In this case he recommends the descaling and dehydrating by the blowpipe, scratch brushing and painting, before condensation of moisture can take place, say within a time lapse of two hours. The use of the scratch brush in preference to using compressed air is stressed, as the latter would nullify the good work done by the flame cleaning.

Would such a treatment be useful for preparing sheets for vitreous enamelling? It certainly would not have the etching effect caused by pickling, which some consider essential as a key for the adhesion of the enamel. It should, however, effectually remove any occluded hydrogen if it were carried out on pickled sheets. It is obviously worth while bearing in mind for experimental work. It is unfortunate that scant mention is made in the article of the possibility of the application to cast iron. Its linear expansion is lower than steel, and there is the additional query as to whether this material would withstand such "shock tactics" without cracking. If it could be applied, it would fit in well in any conveyorised production of standardised parts such as cooker components. Again, there still remains the question of the induction of a roughened face, stated to be essential as a key for enamel adhesion. As a fixture could be made for sweeping completely the surface of the component linearly, local warping should be at a minimum. Again, some experiments directed towards oxy-acetylene cleaning should be worth while. Shot-blasted castings which have been left lying about for a week-end or a holiday shut-down might be so treated, if only to remove dampness. The illustrations in the article show a number of specially-designed blowpipes—some mounted on wheels—for specific duties, and probably this is a prerequisite to success. It is specifically pointed out that, "by means of the high temperature thus applied, the scale is rapidly heated without the overheating of the base metal." It is this phrase which indicates that the application of the process is not ruled out for a material of low elasticity such as cast iron. Moreover, the word "castings" is used in several cases where there is a distinct doubt as to whether iron or steel is indicated.

Typical of this is the following quotation: "Flame descaling is frequently applicable to the removal of scale from castings. On large castings with flat areas and light scale deposit the flat multi-flame tip may be employed. Multi-flame round tips should be used for edges, corners and recesses and for castings having a heavy scale. Hollow cylinders and large pipe interiors may be descaled by means of a broad, flat multi-flame tip assembly mounted on a special carriage. Flame descaling leaves a clean natural surface. There is no chemical or physical action upon or discolouring of the base metal. The descaling is rapid and the process is one that can be fitted into a production line." The scale on either annealed cast iron or steel is stated to be, generally speaking, of the medium thickness and carrying a cracked face "extending in some places for the depth of the top scale and in other spots down to the scale-iron interface. Usually a break will be found at both levels." This appears to us from a general study of the article to be of the type easily removed, for thickness is not the criterion. The scale on castings is stated to be from $\frac{1}{64}$ to $\frac{1}{8}$ in. thick, and under the effect of a suitable flame will fly off in patches ranging from $\frac{1}{4}$ in. to 1 in. wide. As some steel castings have to travel overseas before final assembly, and painting is often carried out before despatch, the process does make an appeal, providing the costs are reasonable. Fortunately the ascertainment of cost per unit area is very easily effected, and it should only vary within very narrow limits.

We have not dealt with the much wider application to structural steels, as herein the position is well set out and appears to be distinctly attractive. A part of the same principle is used when rolling very heavy plates, where it is quite customary to throw upon the white-hot plate quantities of heather. As the plate is carried beneath the rollers, explosions take place, which prevent the scale being rolled into the surface. For the iron and steel foundry industry, a vista is opened for profitable experiment, even if in the early stages it is the casting and not the scale which flies.

Stability in Non-Ferrous Metals

By "Onlooker."

Those who deplore the influence of the speculator on commodity prices and recall only too clearly the numerous occasions during the past decade when the markets have lost all sense of values may, if they are interested in the non-ferrous metals, reflect upon the course of values in Whittington Avenue when the speculator is absent, for the last few months have seen very little speculative activity there. Following the September crisis there was an outburst of such activity, but it was shortlived, and the failure of American business to achieve the spring activity which had been predicted for it has proved since to be a most discouraging factor.

It will be remembered that the last great speculative buying movement on the Metal Exchange occurred in the spring of 1937, and it was based largely on expectations of enormous demand in connection with rearmament, coupled with a belief that supplies would hardly be equal to this demand. The whole affair was, of course, a ramp of the first magnitude, and when the bubble burst the aftermath proved to be both costly and dangerous. However, the London Metal Exchange came through the ordeal very well, although from time to time there was a faint undercurrent of uneasiness.

The Spelter Position

As already mentioned, there has not been any serious speculative activity in metals since October last, for conditions have been such that operators have feared to launch out in any direction. A study of the course of prices reveals the fact that movements have been within narrow limits, and that on the whole quotations have been remarkably steady. Of late tin has displayed a very firm tone, and the market has developed a premium for cash, but there is nothing special to report in the other metals. In considering this question of price stability one must of course remember that in copper and tin at any rate there is a fairly rigid system of control which can and does operate to vary the rate of production, while in lead the producers have an understanding which, however, lacks the formality of the tin and copper agreements. Spelter alone is not the subject of any artificial measures, and until the long-awaited decision about the duty revision is made there cannot be any question of establishing a cartel which would enable agreement on the vexed question of curtailment and quotas. It is not altogether surprising, therefore, that spelter remains persistently at a lower price than lead, which it normally transcends in value.

It is obvious that a system of output control is instituted because producers feel that the price is suffering, or is likely to suffer, because the statistical position is getting out of alignment, and from this it follows that interested parties must have in mind some level for the quotation which they consider right and proper in existing circumstances. Last autumn, when the copper producers made two changes in the rate of output rather close to each other, they came in for a certain amount of criticism, one suggestion being that they cared more for holding up the price than for the maintenance of world stocks at a reasonable level. There is also much criticism of the action taken by the tin people in creating a Pool and holding many thousands of tons of metal off the market at a time when the shortage of early tin is such that a backwardation rules, a stiff premium being asked for the cash position. As things are, however, there cannot be any doubt that a very fair measure of price stability in the non-ferrous metals has been secured and consumers have less anxiety accordingly.

A.R.P. for Factories

STANDARD REQUIREMENTS

There has been issued recently the draft of the provisional Code provided for in the Civil Defence Bill giving the standard requirements for the protection of persons working in factories and commercial buildings. The Code prescribes standards for lateral and overhead protection, it being pointed out that alternative materials can only be permitted when specially authorised. For shelters in buildings it is necessary to provide a roof or floor over having sufficient strength to support the fall of *débris* if the superstructure should be demolished. Superimposed loads, given in a table, are additional to the normal superimposed and dead loads which the floor or roof would be designed to carry for normal purposes, and support must be given where necessary to the floor panels as well as to main beams and joists.

Rules are given for calculating the number of persons who can be accommodated in shelters ventilated naturally by way of normal exits and entrances, but without mechanical ventilation. In order to minimise the number of casualties likely to result from a direct hit, shelters should preferably be limited to parties of not more than 50 persons, the distance between shelters being recommended to be not less than 25 ft. in any direction, and 40 ft. to 50 ft. spacing is preferable. In order to provide an alternative means of exit in case the normal entrance should be blocked, each shelter must have two entrances situated as far as possible from each other. Only in exceptional circumstances should shelters be provided on floors above the ground floor of any building, and in such cases the work should only be carried out under expert advice. The choice of the type and position of shelters outside buildings will nearly always be governed by site conditions. Every advantage should naturally be taken of favourable site features. The shelters should be kept at a safe distance from high buildings, chimney-stacks, water-towers, etc., so that in the event of a collapse of any part of these structures the shelters will not be damaged by falling *débris*. Except where excavated in hard rock, it will be necessary to provide linings for shelters below ground. The linings may consist of concrete cast *in situ*, pre-cast concrete units, or steel units suitably protected against corrosion.

There are four main methods by means of which the required shelter within buildings may be obtained, including refuge in covered trenches or tunnels constructed under the ground floor of the factory; in existing basements; in other suitable rooms, corridors, etc., strengthened where necessary; in specially built shelters within the factory buildings, or in lean-to's.

This and other useful information is contained in the draft, copies of which may be obtained from H.M. Stationery Office, York House, Kingsway, London, W.C.2. (Price 6d.)

Publication Received

Engineering Exports—A Detailed Survey for 1938. Published by the British Engineers' Export Journal, Dorset House, Stamford Street, London, S.E.1. Price 10s. 6d.

This survey has been prepared in folder form and covers exports to 111 countries of 102 classes of goods entering the general classification of machinery. Whilst each annual issue is of itself valuable, the major benefit will accrue when a series can be examined to ascertain any trend in the direction of increased or decreased buying or complete withholding of purchases.

The capital of Herbert Morris, Limited, manufacturers of cranes, conveyors, elevators, etc., is to be increased from £600,000 to £1,000,000 by the creation of 800,000 new 10s. ordinary shares. Of the new shares 200,000 are to be issued immediately to existing ordinary shareholders by way of a capital bonus in the proportion of one new share for every four now held. Reserves to the sum of £100,000 will be capitalised for this purpose. There is no present intention of issuing any further shares.

Random Shots

Although the Petter team made a brave show in the fight for the F.A. Cup, Portsmouth carried off the honours, and their success can be summed up in the remark of the wit who said "that's gland, Pompey!" With the football season over, it seems strange to have to switch over to cricket at a time when it is so cold that no one thinks of discarding his winter "unterpanten," and so wet that the Englishman's proverbial gamp is really justifying its existence. But in spite of adverse climatic conditions, old cricket bats are coming out of dusty cupboards, and fathers are beginning to be worried by schoolboy sons for cash to buy new ones. Any smart parent feeling the draught of a suddenly increased car tax has an adequate retort to pleas that last year's bat is splitting. "I know one man, my son, who has used his bat for centuries" is all he has got to say, and how can that be answered by the youthful worshipper of Hutton?

* * *

As one hurries to or from any of London's great railway termini many thoughts, speakable or unspeakable, pass through the mind, but it rarely occurs to anyone to stop to consider the design and architecture of places so eminently constructed for utilitarian purposes! Yet only recently People-Who-Should-Know have been singing the praises of King's Cross as being a thing of architectural beauty. St. Pancras, too, has had its share of praise for its grace and beauty of form. A pithy criticism of the hotel adjoining St. Pancras once came from the lips of a little girl who was lunching in the grillroom with her father on one of the last days before it was finally closed. The air was heavy with that deep, dignified and sleepy hush which accompanies a carpeted and well conducted grill-room well past its prime. In the midst of the silence a shrill little voice piped out: "Daddy, why are we having lunch in this church?"

* * *

Business men with offices in Victoria Street and its environments will find it a very definite advantage to adopt the black Eden hat. One recent purchaser of such a hat declares that he can now park his car in the backways of Whitehall, places strictly reserved for Civil servants, without question!

* * *

On their return to school after Easter the children were asked to write an essay on how they spent the holiday. Except for the scratching of pens, all was quiet until suddenly one youngster burst into tears. "Please teacher," she sobbed, "somebody's stolen my rock, and now I can't spell Aberystwyth!"

* * *

Lot VII *from the Barrington Hooper Collection.*

There is the story of the skittles champion who was taken to play golf for the first time. When he got back to his favourite skittle alley he was asked what golf was like; but the only comment he could be persuaded to make was: "Believe me or not, chaps, there was times when we was as much as a mile from t' bar."

"The average man doesn't know when he's well off," declares a writer. That's because the average man never is.

"Marksman."

Engineering Wages

Provisional arrangements have been made for a conference between the engineering unions and the National Employers' Federation in London on May 10 to discuss an application for increased wages and improved overtime conditions. A similar application last year was rejected on the ground that the industry could not afford to pay increased rates.

Foundry Melting Furnaces*

By S. E. DAWSON, F.I.C., A.M.C.Tech. (Stanton Ironworks Company, Limited)

The development of the high-duty cast irons by modification of the structure, or by alloy additions, has naturally resulted in improved melting practice, in which higher temperatures and more exact control have generally been sought.

In an examination of the different methods of melting in the foundry, it is of some importance to keep in mind, in the first instance, the cost of melting in each type of furnace, exclusive of materials charged and apart from the merits belonging to each, and whilst it is somewhat difficult to show this exactly, owing to their different capacities and principles involved, the following may be taken as approximate figures for such sizes as are in common use:—

Cupola: 10s. to 15s. per ton.
Crucible: 55s. to 90s. per ton.
Rotary, coal-fired, 15s. to 20s. per ton.
Rotary, oil-fired, 20s. to 30s. per ton.
Electric furnace, 50s. to 60s. per ton.

Considerably lower melting costs than these prevail in many foundries where continuous melting over long periods is in operation.

Other factors to be considered in reviewing the various melting units are generally with regard to the quality of metal required, and the size and frequency of supply demanded by the class of casting to be made in the foundry concerned.

Influence on Fundamental Properties

It has long been recognised that the method of melting cast iron may have considerable influence on some of its fundamental properties. As an inherent part of such processes of melting commonly used in the foundry, there are usually one or more characteristics which may be considered as influencing the resulting product, although it is not altogether clear at present how these may be correlated. Such factors include, in addition to the type of raw material employed, the temperature attained during melting, the time of operation, the extent of contact with, and nature of, gases and slag. These are to some extent interdependent on each other, *i.e.*, a variation in one will automatically bring about changes in other conditions, which may cause modification of the cast iron in respect of structure and physical properties. Where parts of the charge are added subsequent to the melting of the main bath of metal, as in open-hearth and crucible melting, altered structures may also result.

Recent investigations into cast iron of similar chemical analysis, though of different physical properties, indicate that the amount and condition of the graphitic carbon has a large bearing on such variations. The effect of rate of cooling and composition on the graphite is already well known, and follows well-defined laws, but may be further modified by melting conditions. In this connection, the part played by the absorbed gases is still to be fully investigated, although the effect of certain non-metallic inclusions on the graphite size has already been shown to be of considerable importance.

Norbury and Morgan† suggest that the presence of solid inclusions promotes larger graphite growth, whilst supercooling to form fine graphite occurs if the inclusions are liquid. They have shown that if the irons containing such inclusions, as almost all cast irons do, are subjected to oxidising gases, fine graphite results, whilst with reducing gases, coarser forms are precipitated. This is found to take place in the presence of titanium, the oxide of which reduces the melting point of slag, possibly coating the inclusion with a fluid or semi-fluid exterior, and so rendering it innocuous as a graphite precipitant.

In practice, however, the gas used is carbon dioxide, which is bubbled through the molten iron for a few minutes, when a progressive refinement of the graphite takes place. Conversely, if this treated metal is subjected to a reducing gas, such as hydrogen, the iron reverts to a coarser graphite structure.

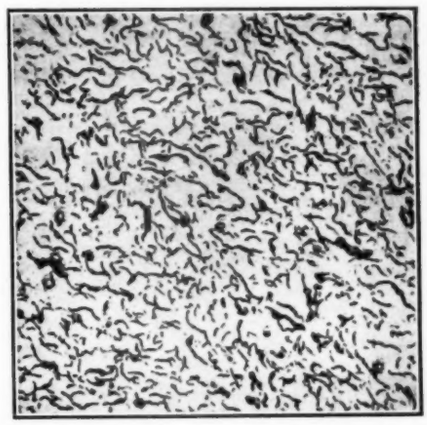
The presence of titanium is, however, essential and must be added to those irons, such as hematite, which are deficient in this element. Those irons, however, including many of the phosphoric ones, containing about 0.25 per cent. titanium, react readily to this treatment. The process‡ works well in the crucible type of furnace, but ordinary cupola-melted metal offers some difficulty, possibly due to the intimate contact with coke affecting the silicate inclusion, as shown by the greater ease of production of the supercooled structure when melted in the presence of charcoal. Present investigations suggest, however, that the condition of the slag inclusions in the initial pig-iron may have an important bearing on the result. It will be understood that as no counter-precipitant should be present, the amount of carbon should be such as to avoid the formation of kish.

The matrix in cast irons modified by this process is largely ferritic, the carbide separating from solid solution being more readily decomposed. Such irons have a greatly increased strength compared with the normal iron before treatment, tensile strengths of 30 tons per sq. in. being obtained by oil quenching from 900 deg. C. and tempering at 550 deg. C. Better fluidity and soundness of casting, even where varying sections occur, are marked characteristics of metal treated under this process.

The effect of oxidation by carbon dioxide in the presence of titanium is seen in Fig. 1, which shows the structures of an iron before and after treatment. Cast irons melted under constant conditions in the cupola or in the electric furnace, from pig-irons produced under different conditions, have shown the same characteristics as the parent pig-iron, even after repeated remelting. The effect of the quality of coke, in the case of the cupola, also has an appreciable influence on the character of the iron, charcoal-melted irons having 20 per cent higher physical strengths than the same irons melted with ordinary coke. With these considerations in mind, it might now be profitable to consider the various melting units in detail.

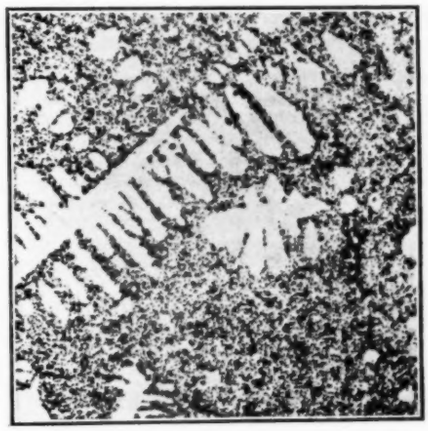
The author then dealt with the cupola, and included material printed in our issue of January 27, 1938, p. 97, *et seq.* After describing the balanced-blast cupola, he terminated his Paper with material upon which he based his Paper "Melting of Cast Iron in the Foundry." This was printed in our issue of March 10, 1938, p. 219, *et seq.*

BEFORE TREATMENT. × 500.



AFTER TREATMENT. × 500.

BEFORE TREATMENT. × 50.



AFTER TREATMENT. × 50.

FIG. 1.—EFFECT OF CARBON-DIOXIDE TREATMENT ON CAST IRON IN THE PRESENCE OF TITANIUM. ALL ETCHED.

* Extract from a Paper read before the Birmingham, Coventry and West Midlands Branch of the Institute of British Foundrymen, Mr. L. W. Bolton presiding.

† Iron and Steel Institute, 1936.

‡ B.C.I.R.A. Patent No. 425,277/35.

DISCUSSION

Importance of Shop Requirements

The Chairman (Mr. L. W. Bolton) expressed full agreement with Mr. Dawson's argument that, to obtain the best efficiency from the cupola, it was advisable to run it at its maximum output rather than to reduce the blast during the melt. He had been trying to persuade founders that they should run their foundry to suit the cupola instead of running the cupola to suit the foundry. As a general rule, small foundries expected too much from the cupola, for they hoped to obtain good results with the cupola running much below its normal output. If arrangements could be made to reduce the melting period, and the cupola was run at its maximum output, better results would be forthcoming. Although the use of the gases from the top of the furnace to pre-heat the air blast in the hot-blast cupola of the Griffin type appeared to be wrong theoretically, after studying that type of furnace he had arrived at the conclusion that it resulted in some improvement. The cupola seemed to run more smoothly and simpler control was secured when the blast was pre-heated. With regard to the use of more expensive bricks in the melting zone and a cheaper quality above, he did not think the quality of the bricks really entered into the question, it being the quality of the patching that counted. No matter how good the bricks were, if the patching was poor they would not get a long life.

Mr. Dawson agreed with Mr. Bolton that quicker melting over a shorter period would be better generally if it could be managed. He pointed out that in America, where the hot-blast type of cupola was used, a high carbon content was aimed at. However, he did not think that the structure of American iron was quite so good as that of English iron, which was lower in carbon. So far as the choice of bricks for the melting zone was concerned, he had had experience of both short and long blasts. He had always found that a good foundation brick helped in maintaining the lining of a cupola. It was useless relying upon good-quality patching if the background was of inferior quality.

Answering Mr. Blythe, Mr. Dawson said that up to a point he was in agreement with him that it was best to put the coke in first and then the pig-iron. Generally, the coke was put on separately from the iron, but many cupolas mixed it, and they seemed to get equally good results. He did not think it mattered much, but where steel was being melted it was best to put the steel next to the coke.

Rotary-Furnace Costs

Mr. G. R. Shotton asked if the approximate melting costs of the different types of rotary furnaces given by Mr. Dawson had included labour costs. He had stated that for the coal-fired type the cost was approximately 15s. to 20s. per ton of metal, while the oil-fired rotary was 20s. to 30s. per ton. He took it that the labour charge was similar in both cases, and that they could assume that the oil consumption was 30 to 50 per cent. higher than that of coal.

Mr. Dawson replied that the difference in the costs he gave was due to the difference between the cost of coal and oil. He could supply Mr. Shotton with figures as to costs in both cases and also in regard to melting losses in the rotary type of furnace. The latter were slightly less than those obtained from the cupola furnace. So far as any pick-up from ash was concerned, it did not enter into the question because it did not remain in the furnace but went into the flues.

Pulverised-Fuel-Fired Non-Ferrous Furnaces

Mr. Hudson asked if Mr. Dawson had had any experience in the use of pulverised coal for crucible furnaces in connection with the melting of non-ferrous metals. He wondered if there would be any benefit in heating the air.

While he had not had any experience in pulverised coal for heating rotary furnaces Mr. Dawson thought some benefit would be derived from heating the blast. Early ignition of the coal dust was required. Everything depended, however, on the type of coal used.

Replying to Mr. A. G. Harrison, Mr. Dawson said that it had not been determined that the slag in the cupola and that found in the iron were the same material. The atmospheric conditions could be so arranged as to give an all-round improvement in the type of slag inclusion, even if it was not of the same type as that in the cupola. The combustion of the gases in the blast furnace would also contribute to it. In the same way, if the pig-iron was melted under conditions which would need to be determined he thought the type of pig-iron produced could be fairly well controlled, or better controlled than it was to-day.

Quality of British and Foreign Pig-Irons

Mr. J. J. Sheehan disagreed with Mr. Dawson in regard to the qualities of American and British iron. He had tested British, Continental and American iron, and the last-named was superior due, he believed, to better control in the blast furnace. He also disagreed with him in regard to the relative life of lining. He had found that the life of the lining in a hot-blast cupola was three times that of the ordinary cupola. That was due to the fact that the pressure was a third to a half of what it was in the ordinary cupola, and thus the erosion was considerably reduced. He was anxious to know how Mr. Dawson would run a cupola to suit the foundry. How could a cupola be operated on half or quarter blast, as was sometimes necessary?

Mr. Dawson pointed out that for several years he worked for an American company, and English iron was sent both to the parent company in the States and also to the German factories of the concern. Better results were obtained with the English iron than the company was getting with American. American iron was higher in carbon and lower in silicon; for equal composition it was slightly softer and more easy to work than the English iron. There were, however, many good American irons as well as good English irons. It certainly was difficult to run a cupola on half or quarter blast economically.

On the proposition of Mr. J. Hird, seconded by Mr. G. F. Thonger, a hearty vote of thanks was accorded Mr. Dawson for his Paper.

(*Continued from next column.*)

silica sheath is over the centre of the bath, to dip the fork until the sheath is fully immersed, and when temperature equilibrium has been reached by the couple, to withdraw the apparatus. On withdrawal, the sheath, though rendered unsound by its coating of slag, is found to have protected the couple. The silica sheath, and occasionally the end block of diatomite, must be replaced—which operation can be effected in a few minutes and at small cost—the apparatus being then ready for another immersion. In practice, it is found advisable to protect the silica sheath with a thin sheath of steel. This serves to keep the silica from contact with the slag during the dipping movement, and, on melting, to expose the sheath to the liquid steel, as desired. The time of immersion required to obtain a reading depends on the details of mounting of the thermocouple junction and the response time of the indicator, and can be reduced to as little as 4 secs. The thermocouple, owing to its short exposure in the hot region, can be immersed repeatedly before contamination becomes appreciable.

It may be added that apparatus designed by the Laboratory on the above-mentioned principles is now in regular use at the steelworks in Sheffield where the experiments were carried out, and that similar apparatus is on trial at several other works.

Temperature of Molten Steel

The Annual Report of the National Physical Laboratory* issued recently, contains particulars with regard to research carried out in the Physics Department on the temperature of molten steel. Appended is a brief account of the work.

Temperature of Liquid Steel

The investigation of the temperature of liquid steel, both before and after being tapped from an open-hearth furnace, which was undertaken for a joint committee of the Iron and Steel Institute and the British Iron and Steel Federation, is now practically complete. In the series of operations from the melting of the steel in the furnace to the casting of it in the mould, several stages occur at which the measurement of temperature is feasible, *viz.*, (1) in the furnace, (2) in the launder stream, between the furnace and the ladle, (3) in the ladle, (4) in the stream between the ladle and the mould, or in the trough between the two, if one is used, and (5) in the mould. A measurement at (1) is obviously the most important, since at this stage the temperature is controllable.

In general steel practice, at any rate in this country, a routine of temperature measurement has only been attempted at stages (2) and (4)—by sighting an optical pyrometer on the stream. Owing to the low emissivity of the metal surface, such measurements may be as much as 150 deg. C. below the true temperature. The necessity of applying a large and somewhat uncertain correction is a serious drawback to the method.

The Laboratory decided to employ a platinum thermocouple, using a "quick-immersion" technique. Small-scale experiments showed that such a couple, lightly sheathed in silica, withstood immersion for some 20 secs. in liquid steel, at temperatures ranging up to a maximum of 1,690 deg. C.† without fracture of the sheath or apparent depreciation of the couple; that, though the silica softened and tended to collapse, as many as twelve successive immersions could be obtained with a single sheath at 1,620 deg. C.; and that the thermocouple reached temperature equilibrium in 10 or 15 secs. and gave satisfactory agreement with an optical pyrometer working under black-body conditions.

The mounting finally adopted for use in the actual furnace is as follows:—A steel pipe, some 10 or 12 ft. long, is clamped to a standard charging "fork," which can be picked up by the furnace charger and inserted into the furnace: to the end of the pipe is attached at right-angles another pipe 18 in. long, terminating in an orifice into which the silica sheath of the couple is wedged by a packing of asbestos wool. The whole of the metal parts are encased in an insulating layer of light diatomite brick 1½ in. thick. This material, during the 20 or 30 secs. for which the apparatus may have to remain in the furnace enclosure, prevents any noticeable rise in temperature inside the pipe, and so renders it possible to carry the compensating leads as far as the right-angled bend, where union is made with the couple. For that part of the diatomite brick next to the silica sheath, which is subjected during immersion to both molten steel and slag, a special "heavy" grade of the material is used which withstands the conditions for some eight or ten immersions.

The procedure in making a measurement is to insert the fork into the furnace, so that the

(*Continued in previous column.*)

* H.M. Stationery Office, York House, Kingsway, London, W.C.2. (Price, 2s. 6d.)

† The highest temperature reached by liquid steel in an open-hearth furnace is about 1,650 deg. C.

New Foundry for Pipe Specials

RECENT DEVELOPMENTS AT STANTON

The range of mass-produced special castings has recently been considerably increased at the Stanton Works of the Stanton Ironworks Company, Limited, by the opening of a new shop devoted entirely to the manufacture of this class of casting. This new extension is really the continuation of a programme which commenced in 1931 with the erection at their Holwell Works of what is still the largest and most up-to-date continuous casting plant for the manufacture of the smaller sizes of special castings up to 6-in. diameter. The popularity of the castings produced on this original plant necessitated its duplication by a second plant in 1937.

In the third recently-completed plant, which caters for sizes of special castings up to 12-in. diameter, it has not been possible, owing to the wider range of sizes covered and the lesser demand for these larger sizes, to mechanise the various stages of production to the same extent as was possible with the Holwell plants, but nevertheless the new plant represents a vast improvement in both working conditions and output per man on previous methods.

The building housing the new plant was originally part of one of the vertical pipe-casting foundries, the need for which no longer existed on account of the advent of the superior spun pipe. Consequently the new plant has taken the name of the old shop and is known as the South View Specials Foundry.

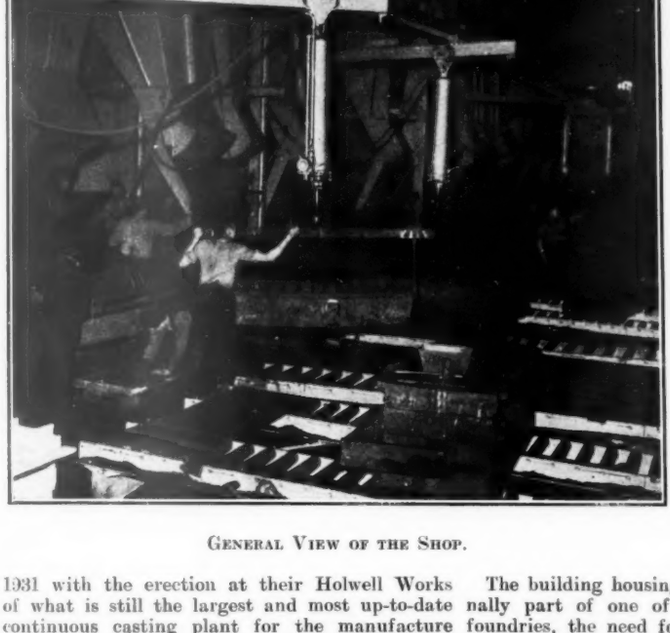
The moulding machines, which have been designed and manufactured in the company's own works, are of the hand-operated turnover type. The weight of the moulding box is counterbalanced by an adjustable weight which can be altered according to the type of casting being produced. These machines, eight in number, have been erected in pairs, each pair being served by a 3-ton electrically-operated jib crane.

Permanent metal patterns and machined moulding boxes are employed and the moulds are rammed by pneumatic hand rammers. The sand is fed to the machines from overhead hoppers.

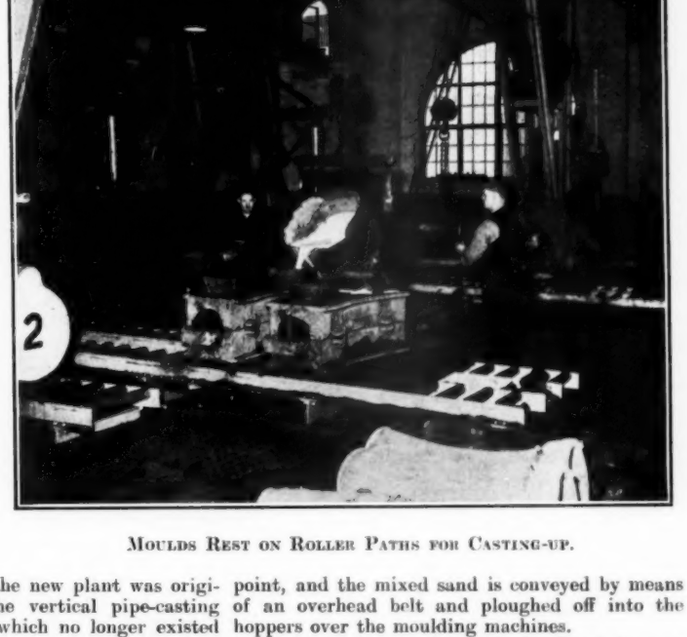
An up-to-date reconditioning plant has been installed in which sand is conveyed from the underside of the knock-out platforms, over a magnetic separator, to a mixer. The requisite quantity of new sand and water is added at this point, and the mixed sand is conveyed by means of an overhead belt and ploughed off into the hoppers over the moulding machines.

The cores are made singly by hand in permanent metal coreboxes. The core-irons are provided with machined bosses which, when the moulds are assembled, seat on to machined faces on the moulding boxes, thus ensuring uniformity of the thickness of the castings.

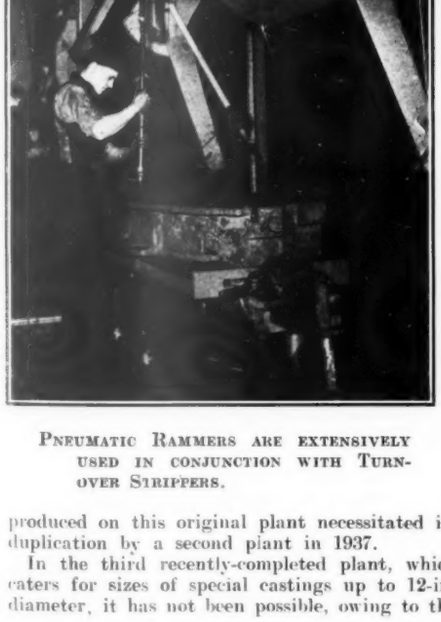
The layout of the shop is simple but effective. The four pairs of moulding machines are situated along one side and casting is carried out on the opposite side. The completed moulds are conveyed from one side to the other by means of parallel sets of gravity roller-conveyors. At the end of each set of conveyors, a knock-out platform is provided on to which the boxes are placed after cooling. Return conveyors carry the empty moulding boxes back to the machines.



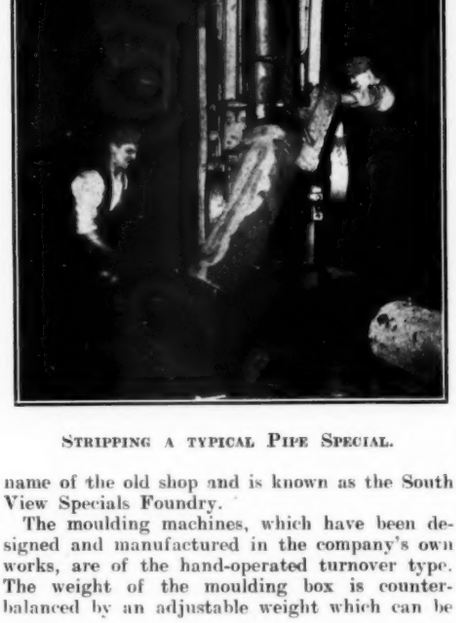
GENERAL VIEW OF THE SHOP.



MOULDS REST ON ROLLER PATHS FOR CASTING-UP.



PNEUMATIC RAMMERS ARE EXTENSIVELY USED IN CONJUNCTION WITH TURNOVER STRIPPERS.



STRIPPING A TYPICAL PIPE SPECIAL.

Catalogue Received

Steel Bars. The new catalogue just issued by Kirkstall Forge, Limited, of Leeds, is a brilliant piece of publicity. It contains 122 well-illustrated pages and is particularly comprehensive. Some interesting notes are given of the history of the works, which takes one back to 1152, the foundation of Kirkstall Abbey. After a description of the shops and metallurgical research department, there are eight pages of definitions of technical expressions. These are followed by a wealth of data on the bars manufactured and the specifications issued by the various standardising authorities. Finally, the last 18 pages contain a well-selected collection of conversion tables and technical data. The reviewer congratulates the metallurgical department of Kirkstall Forge which, it is stated, has been responsible for the preparation of this catalogue.

D

Porosity and Sinking in Cast Iron

SOME NEW EXPERIMENTAL EVIDENCE

By W. WEST and C. C. HODGSON (Leyland Motors, Limited)

(*Concluded from page 346.*)

PART II.—THE RELATIONSHIP BETWEEN SAND AND SOUNDNESS

The experiments recorded in Part I of the Paper represent only a portion of those made on similar lines, and their execution extended intermittently over a considerable period of time. During this time the authors were not unmindful of the possible influence of sand and mould conditions. It was suggested that the action of hand-pressing set up conditions in the mould that were different from those present when hand-ramming. The sinking defect was stated to be much more prevalent on hand-pressed than on hand-rammed work, but experiments made later to establish this showed it to be erroneous, the error being due, apparently, to a failure to appreciate that in many instances an attempt was being made to compare green sand in the one instance with dry sand in the other. However, before these points were brought out, some preliminary work was done on sand, and although the results have no direct bearing on the subject of this Paper, they seem to be of sufficient interest to justify their inclusion.

TABLE XIVA.

	Position of test cylinder (See Fig. 19).	Green permeability. Seconds.	Green compression. Lbs. per sq. in.
Hand-rammed; average of six moulds made by operator No. 1	A	34	2.2
	B	33	2.1
	C	74	3.0
Hand-rammed; average of six moulds made by operator No. 2	A	53	2.7
	B	73	3.9
	C	74	5.7
Hand-pressed; average of six moulds made by operator No. 3	A	74	7.4
	B	97	7.6
	C	87	14.7
Hand-pressed; average of six moulds made by operator No. 4	A	58	4.0
	B	91	6.2
	C	94	9.8

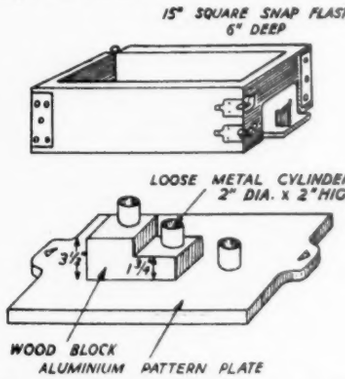


FIG. 19.—PATTERN-PLATE AND PATTERN SHOWING POSITION FROM WHICH SAND SPECIMENS WERE TAKEN. THE TEST CYLINDERS REFERRED TO IN TABLE XIVA ARE (A) EXTREME RIGHT, (B) CENTRE, AND (C) THE EXTREME LEFT.

Assuming for the moment that the sinking was in some way connected with the method of moulding, the cause might be the difference in the consistency of the sand. For instance, it can be imagined that if the sand varied much in permeability, gas flow would be greatest where the permeability was high, and consequently there might be a considerable difference in the temperature of the sand at the time the mould was completely filled, and that sinking might take place in an overheated region. Again, where the sand had been pressed very hard and had high strength and poor permeability, the metal might not lie satisfactorily.

In order to determine what difference in permeability existed between hand-rammed moulds and moulds made on a hand-press machine, a wooden pattern was made, having two steps, the first 1¾ in. high and the second 3½ in. high. This was placed on an aluminium bottom-plate inside a 15 in. square snap-flask 6 in. deep. The moulds were made up in the ordinary way and thin sheet-metal cylinders 2 in. internal diameter by 2 in. high, made of 20-gauge material, were then pushed through the sand until their lower edges came into contact either with the aluminium pattern-plate or the steps on the wooden pattern (Fig. 19). The cylinders were sharpened at their entering ends to assist penetration without disturbing the sand. The cylinders, with sand still *in situ*, were then cut from the moulds and permeability and compression tests made. Green sand similar to that for which details have already been given was used; average tests of this sand gave:—Moisture, 5.8 per cent.; green permeability, 125 secs.; green compression, 9.5 lbs. per sq. in.; and loss on ignition, 5.7 per cent.

The results obtained are contained in Table XIVA. It would be idle to contend that such large differences are without influence upon the manner of solidification of cast iron in a sand mould, but in this instance no connection has been established between sinking and method of moulding. The present indication is that actual method of moulding, *i.e.*, whether hand-rammed or pressed, is without influence on the main problem. The specimens were rammed with a B.C.I.R.A. pattern of A.F.A. rammer, and permeability was determined with the B.C.I.R.A. permeability apparatus, and compression strength in a Dietert compression machine.

Green-Sand *versus* Dried Moulds

It is a well-known fact that better castings can be obtained from dried than from green-sand moulds, but to conclude from this that drying is the dominant factor would be, in many instances, an unwarranted assumption, for often the sands used for the two types of moulds are entirely different from each other. Particulars of the "black" sand used throughout these experiments have been given in Part I. Particulars of one of the sands used by the authors for dry-sand work are given below, and this sand mixture has been used where "brown" sand moulds are referred to in the experiments in the following section:—York yellow, 6 parts; Leighton Buzzard, 2 parts; used sand, 22 parts; and a half-pint of dextrine to each 4 cwts.

When considering the difference in behaviour of metal cast in green sand and dry sand, the two most important variants appear to be sand make-up and the amount of moisture present. If sound castings are obtained from "brown" sand dried moulds and castings with external sinks from "black" sand moulds cast green, is it possible to reverse the results by casting into the normally dried "brown" sand green, and into the normally cast green "black" sand after drying?

In order to determine this, two sets of experiments were made, in which the normal method of using the two sands was compared with methods reversed; the results of these experiments are summarised in Table XV. It will be seen that both sand mixtures give sound castings when the moulds are dried, and that external sinking takes place when they are used green, and from this it would seem that the moisture in the sand is the determining factor. The influence of the blacking used on the sur-

TABLE XV.—*Comparison of Castings made in Dry-Sand and Green-Sand Moulds.*

Type of Casting:—Stabilus body, hand-pressed, cast one per box, two boxes. Method of Melting:—Production cupola.

Charge:—Pig C, ½ cwt.; pig G, 2½ cwt.; pig H, 2½ cwt.; pig J, 1 cwt. Cylinder scrap, 3½ cwt. Casting temperature, 1,330 deg. C.		*Charge*:—Pig H, 2 cwt.; pig J, 1 cwt.; pig F, 3¾ cwt. Cylinder scrap, 3½ cwt. Casting temperature, 1,390 deg. C.	
Type of mould.	Condition of castings.	Type of mould.	Condition of castings.
Black sand, cast green ..	One box only, casting sunk	Black sand, cast green ..	Both castings showing external sinking.
Black sand, dried and blacked	No castings showing external sinking	Black sand, dried and blacked	No castings showing external sinking.
Brown sand, cast green..	Both castings showing external sinking	Brown sand, cast green ..	Both castings showing external sinking.
Brown sand, dried and blacked	No castings showing external sinking	Brown sand, dried and blacked	No castings showing external sinking.
Analysis:—C, 3.45; Si, 2.02; Mn, 0.85; S, 0.12; P, 0.26; and Cr, 0.24 per cent.		*Analysis*:—C, 3.28; Si, 2.07; Mn, 0.86; S, 0.12; P, 0.17; and Cr, 0.27 per cent.	

TABLE XVI.—*Influence of Blacking the Mould Surface on External Sinking.*

Type of casting:—Stabilus body, moulds hand rammed. Method of melting:—Production cupola.
Charge:—
Pig C, ½ cwt.; pig F, 2 cwt.; pig H, 3 cwt.; pig J, 1 cwt. Cylinder scrap, 3½ cwt.
Casting temperature:—
First casting, 1,360 deg. C.; last casting, 1,340 deg. C.

Type of mould.	Condition of castings.	Order of casting.
Black sand, cast green	Both castings show deep sinks between bosses; one casting hollow in one box	5
Black sand, dried, not blacked ..	Neither casting with external sinks	4
Black sand, blacked and dried ..	Neither casting with external sinks	3
Brown sand, dried, not blacked ..	Neither casting with external sinks	2
Brown sand, blacked and dried ..	Neither casting with external sinks	1

Analysis:—C, 3.15; Si, 1.96; Mn, 0.73; S, 0.13; P, 0.24; and Cr, 0.22 per cent.

faces of the dried moulds remained undetermined, and, as it was possible that this was not unimportant, another series of experiments was made to determine the possible influence of blacking the mould surface before drying. The results have been collected in Table XVI, and it will be seen from these that sinking is uninfluenced by the presence or absence of blacking from the surface of the dried moulds.

A final batch of castings was made in which the influence of having one half of the mould dry and the other green was determined, and also the influence of somewhat increasing the size of the ingate used for an all-green mould. A check test in dry sand was included in the series, and B.C.I.R.A. shrinkage spheres as well as stabilus bodies were cast (Table XVII). The D-section runner for the shrinkage spheres which should have had a radius of ¼ in. was cut larger in error, but the runner joining the two spheres had the standard ¼ in diameter.

The shrinkage spheres are shown in Fig. 20, and one of each pair sectioned in Fig. 21. The spheres cast in green sand and those cast in the mould having a dry-sand bottom part and green-sand top part were very similar in appearance externally; they had a thin skin of metal almost completely covering their shrinkage cavities beneath, the cavities themselves being roughly spherical in shape. The spheres cast in moulds with dry top and green bottom sank less than those cast in a mould made wholly in green sand, or with the top part in green sand. The behaviour in green sand indicates that a thin skin of solidified metal is formed almost immediately the mould is full, at least when casting components such as these test spheres; the moist sand acts as a mild chill.

The specimens cast with green-sand bottom and dry-sand top have characteristics which one would expect from a casting cast in a chill with a refractory top; the skin of the top-half has evidently not solidified as quickly as those of the two previous examples, and it contains a large open sink. To be in conformity one would expect the spheres cast entirely in dry sand to have solidified still more slowly and to have shown a still larger open sink at their upper surfaces, but actually they are almost entirely free from any obvious external sinking or internal shrinkage. To elucidate this apparent anomaly will be to elucidate the phenomenon of sinking in castings, or at least go a long way towards it.

While the results from the foregoing experiments do not define any clear foundry practice which would give outstanding results in advance of that already known, certain deductions can be made. The most direct method of avoiding external sinking in cast iron is to maintain the total carbon content over 3.5 per cent. This shows that there is a definite connection between the two factors. The disadvantage of following this practice is that, in castings of any other than plain design, internal porosity at heavy sections will occur. That internal porosity can be dispersed in high total-carbon iron by the treatment of ferro-silicon-titanium has been clearly shown by the respective experiments. To what extent this can be carried out has not been proved, and this point awaits further development.

TABLE XVII.—*Comparison of Castings Made in Dry-Sand and Green-Sand Moulds.*

Method of melting :—Production cupola.
Charge :—Pig H, 2 cwts.; pig J, 1 cwt.; pig F, 3½ cwts. Cylinder scrap, 3½ cwts.
Casting temperature :—First casting 1,330 deg. C.; last casting, 1,300 deg. C.
Method of moulding :—Hand-rammed; parts of moulds that were dried were blacked in the wet state; green-sand parts not blacked.
Sand :—Black sand.

Type of mould.	Order of casting.	Stabilus bodies, four castings cast, one per box.	Shrinkage spheres.
Dry-sand top	3	One blown on boss (or small open sink)	—
Green-sand bottom	4	—	Large open saucer-shaped sinks with small exudations.
Green-sand top	1	Two badly-sunken. One slightly sunken	—
Dry-sand bottom	6	—	Large spherical sink with exudation at bottom.
Dry-sand top and bottom	2	Free from external sinking ..	—
	5	—	Slight depression with exudation.
Green-sand top and bottom, with increased size of runner and gates on stabilus bodies ..	8	Three badly sunken	—
	7	—	Large spherical sink with exudation at bottom.

Analysis :—C, 3.22; Si, 2.08; Mn, 0.03; S, 0.13; P, 0.19; and Cr, 0.25 per cent.

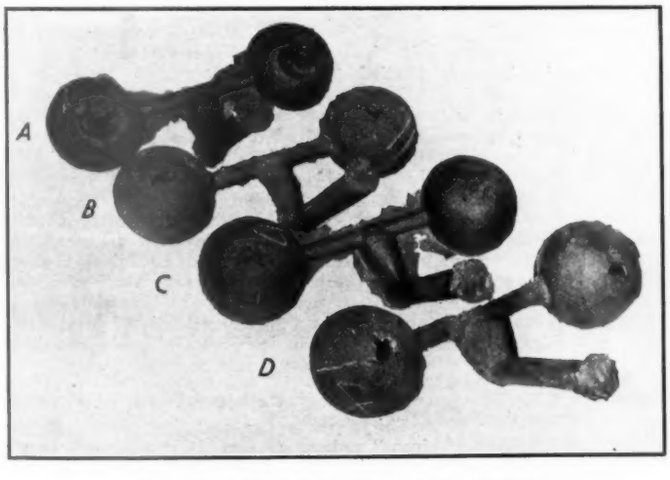


FIG. 20.—B.C.I.R.A. SHRINKAGE SPHERES.

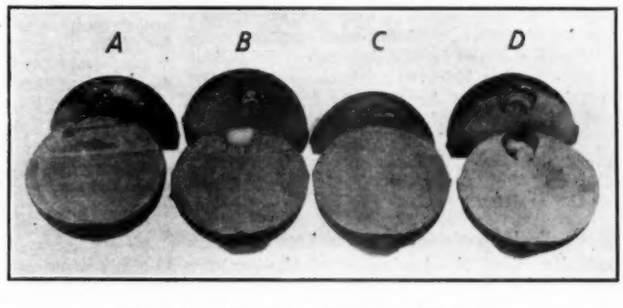


FIG. 21.—SHRINKAGE SPHERES SECTIONED.

On the other hand, the "sinking effect" brought about by the use of lower total-carbon cast iron when using green-sand moulds can be avoided by casting into moulds which have been previously dried.

The explanation for this difference in behaviour is not so easy; that it is directly connected with the presence of gas at the time of solidification is highly probable.

Examples of this can be found by casting other metals such as steel or aluminium in a chill mould in which the metal sets with little or no evidence of gas being present, yet the same metal cast into green-sand moulds can show an amount of gas sufficient to form a "cauliflower" head on the risers. Further to this, the suggestion has been put forward in a certain quarter that the liquid metal is capable of breaking down a proportion of water vapour from a green-sand mould, to create in the metal a hydrogen absorption sufficient to cause the "sinking effect" during solidification.

CONCLUSIONS

(1) High-carbon cast iron composed of pigs from different sources may vary considerably in mechanical properties, although their chemical compositions may be similar.

(2) Changes in casting temperature affect the strength of some high-carbon cast irons more than others of similar composition but different structure. Irons which show well-marked pearlite cell walls and fine graphite are influenced less than irons in which the graphite exists as large flakes.

(3) Treatment with ferro-silicon-titanium effects a marked improvement in the mechanical properties of low-strength high-carbon cast irons. Additional treatment with carbon dioxide did not affect the results obtained to any noteworthy extent. Carbon-dioxide treatment does not appear to be a method that can be conveniently applied in the foundry.

(4) Titanium treatment applied in the crucible produces equally good results irrespective of whether the metal was originally crucible- or cupola-melted.

(5) No marked improvement was found after applying titanium treatment to medium-strength irons.

(6) Castings made from irons which solidify with a pearlite cellular structure are denser and less subject to internal porosity (shrinkage) than those made from irons which do show this characteristic. Titanium additions greatly assist in the production of this type of structure.

(7) The method by which the moulds are made (*i.e.*, whether hand rammed or pressed) is not of primary importance in relation to the phenomenon of external sinking.

(8) Titanium treatment is not effective in preventing pronounced examples of external sinking.

(9) Castings made in dried moulds are less susceptible to external sinking than those made in green sand.

(10) Provided that the moulds are dried, the composition of the sand does not seem to be of importance in relation to the sinking phenomenon.

Thirty Years of Progress in Cast Iron*

By ARTHUR B. EVEREST, Ph.D.

Edwardian Conditions

Thirty years back takes the subject to the year 1909, and it is interesting to reflect for a little while how different life was at that time from what it is to-day. For example, the motor car was still a curiosity and had barely penetrated to some of the more remote parts of the country. Aviation was in its extreme infancy, and was confined to a few hazardous flights in kite-like machines which appeared at exhibitions, and took off if there was no wind. Wireless was still unknown to the man in the street, whilst as for the older engineering institutions, such as railways, building and so on, these were well established, but were not developed to anything like the high state of efficiency associated with them to-day. High-speed records had indeed been achieved on the railways, some of the speeds being, in fact, almost as great as some of the record speeds known to-day, but they were all under conditions of light loading, and not with the heavy loads and long runs which one accepts as a regular feature of the services now. Generally speaking, the whole pace and stress of life then was much lower than it is to-day.

Position of Cast Iron

Cast iron, after a century or more of steady development, was well established as a material of construction, and was regarded as the basis of engineering practice. In fact, one might almost go further and say that, owing to the low stress and strain of engineering practice then, cast iron was perhaps of even wider and greater application than it is to-day. For example, cast-iron bridges had in the past been regarded as the height of engineering development, whilst to-day, of course, alternative materials only would be given consideration.

The whole of the foundry industry, however, up to the time in question had been built up on relatively primitive methods, and the attitude of the engineers towards the foundry art was that it was undoubtedly the Cinderella of the engineering industry. Inside the foundry, rule-of-thumb methods held sway. For example, it was only just about that time some attention was being given to the grading of pig-iron by fracture, while grading by analysis was only just being thought of.

On the other hand, a study of the trade literature of the period in question reveals the interesting fact that whilst some writers were apprehensive of the future, foreseeing the end of the iron-foundry industry with the replacement of castings in iron by castings in steel, non-ferrous alloys and by forgings, nevertheless there seemed to be a streak of optimism amongst the foundry workers, based perhaps on a dormant realisation that technical development might alter the position.

Early Beginnings of Research

Actually, since the beginning of the century a considerable amount of work had been conducted on various aspects of cast-iron development. A great deal of this work was beginning to see the light of day thirty years ago; attention was being given to the possibilities of applying some of the newly developed methods of testing to the products of the iron foundry with, undoubtedly, the ultimate view in mind of adopting such methods for the improvement and control of iron castings. The microscope similarly was arousing interest, and the first steps were being taken to study and to try to elucidate the structure of cast iron, whilst attention was given from time to time to the improvement of melting practice and even to the use of alloy additions.

But as yet cast-iron practice then, and indeed for several years afterwards, seems to have made very little real progress, and practice lagged a long way behind the theories being advanced in the trade papers. For example, the value of carbon control seems early to have been recognised, but the use of steel additions to effect such control was regarded with the greatest suspicion and almost universally as highly dangerous. There were exceptions, however, and one enlightened author stated publicly that he used steel and found it improved the quality of his iron. His method was, however, to place the steel in the form of turnings or sheet scrap in the bottom of the ladle and to tap the iron on to it. The method is stated to have the advantage that if the steel was not dissolved by the first tapping of iron, then it could be used over again.

Thirty years ago the strength of cast iron was in the range of 5 to 8 tons per sq. in., whilst in certain cases (as, for example, in cylinder and other castings made from cold-blast iron) the very high strength of 12 tons per sq. in. was claimed. This was the position which held up to the time of the Great War.

Influence of War Conditions

During the war restrictions on materials and the demand for better castings focused attention on the need for development. Various makeshift expedients were introduced, and for special castings elaborate melting equipment was employed and the use of electric furnaces was quite widely adopted in the iron-foundry industry. The major development, however, established during the war was the use of steel additions for the production of the so-called "semi-steel," the additions being recognised as a means of reducing carbon and controlling composition, and thus improving the properties. It is of special interest to note in this connection that in 1916 J. E. Hurst reported in THE FOUNDRY TRADE JOURNAL the results of a test in which he melted a charge consisting of 100 per cent. steel in the cupola.

The war passed and left the foundry industry with definite developments in cast-iron practice, with greater experience of melting technique and of composition control. These developments, however, cannot be stated to have been generally adopted by the industry, but survived in local areas and in some of the more progressive foundries.

An interesting step in progress was the introduction into this country soon after the war of the Lanz Perlit and the Emmel processes which had been developed in Germany. These irons enabled castings to be produced on a commercial basis with tensile strengths approaching 18 tons per sq. in.

Post-War Developments

After the war more intensive foundry developments became evident, and this period can be called the "alloy cast iron period," which has seen its full realisation in the last ten years. These post-war years have been years of substantial development, and some of the main reasons for this development can be given as the following:—

(1) Engineering progress, and especially the development of the motor vehicle, created a demand for better castings. In this connection the foundry industry owes a great debt of gratitude to the motor-car industry, since no other factor has done so much to revolutionise foundry practice and to create a demand for mass-produced castings of a specialised nature. This demand for castings has, for example, done a great deal towards the development of the moulding machine, the study of special sands, and even, in the U.S.A., in the development of permanent-mould castings. The peculiar requirements of castings for the automobile have all had their effect in the development of foundry metallurgy, which has now led to the extensive use of alloys in castings of difficult section.

(2) The second factor behind the more extensive development of recent years is competition from other materials. For example, the more extended use of aluminium, leading to the development of the light casting industry, has done a great deal to stimulate progress and development in connection with the small iron castings.

(3) Perhaps the greatest factor behind the development in recent years is the extensive metallurgical progress which has been made in this same time in connection with cast iron. Various factors lie behind this progress, as for example, the national recognition of the value of research, which led to the setting-up of the British Cast Iron Research Association. Then, again, there has been increasing technical knowledge of the metallurgy of cast iron from other sources, including individual studies. Much of this activity is now focused in the Technical Committee of the Institute of British Foundrymen.

Alloy Cast Irons

Another factor which has had a substantial influence on progress in recent years is the development of alloy cast irons. The idea of using alloys to improve the properties of cast iron is by no means new. Patent literature shows that the value of nickel, for example, in giving a corrosion-resisting cast iron was appreciated 140 years ago. Studies of the influence of alloy additions were made at intervals at the end of the last century, and in the first part of the present. These researches, however, were in many ways contradictory, and led to no definite conclusion. The reason for the failure of this early work is now appreciated. It was in most cases due to the lack of proper understanding of the behaviour of the base irons to which the alloy additions were made. Failures were due also to the inferior quality of the technique and equipment available for research as a result of which major variations in the variables, such as composition and temperature, completely masked the influence of the special additions being studied.

In the early days of the present century intensive developments had taken place in the alloy steels, and it was realised that, just as in the case of steels, cast iron should logically be benefited by alloy additions; consequently, the study of the influence of alloys progressed, and on their foundation rests the better knowledge of cast iron as it is to-day. The use of alloys has now become an essential and lasting part of foundry practice, and to-day such additions as nickel, chromium, copper, molybdenum and aluminium are firmly established, whilst other special types of iron containing abnormally high silicon and manganese are well known.

Cast Iron To-day

Thirty years ago cast iron was just "cast iron," unless, perhaps, it may have been white iron or even malleable. To-day, however, the term "cast iron" covers a multitude of materials, and even the most hardened and conservative foundryman will be found talking glibly of "austenite," "martensite" and "heat-treatment." In fact, a visit to any ordinary engineering foundry shows that cast iron has grown a long way from its predecessor with a strength of only 5 to 9 tons per sq. in.

To-day grey cast iron includes materials known variously as "high-test" and "high-duty" irons with strengths up to 30 tons per sq. in. "as cast," and which by heat-treatment can have this strength increased further, even up to 40 tons. In a recent report a strength for a cast iron of 63 tons per sq. in. was mentioned, although this cannot be regarded as a

* Extracted from a Paper read before various Branches of the Institute of British Foundrymen.

product suitable for the regular output of a normal foundry. In other directions cast iron, as in the cases of white and chilled irons, has now been improved beyond recognition by means of alloy additions and heat-treatment, whilst it is becoming increasingly the practice to-day even to alloy malleable.

A Modern Classification

A rough classification of the different types of cast iron available to-day might be given as follows:—

(1) High-duty cast irons.
(2 Inoculated cast irons of specially high strength.
(3) Heat-treatable grey or white cast irons.
(4) Specially-hard grey cast irons.
(5) Specially-hard white cast irons.
(6) The heat-resisting and corrosion-resisting austenitic cast irons.
(7) Various special heat-resisting and corrosion-resisting irons of high alloy content, but which are not austenitic.

A reference to the question of strength alone gives some measure of the progress made in recent years. The first national specification issued in 1928 gave the first basis for standardisation for the strength of general grey iron castings. In this case on the 1.2-in. dia. bar, two grades of iron were covered, with strengths of 9 and 11 tons per sq. in. Only ten years later, namely in 1938, progress in cast iron had been so rapid that it was felt necessary to issue a further specification, and B.S.S. 786 was prepared. Three grades superior to those included in the first specification were covered, these having strengths of 14, 17 and 20 tons per sq. in. respectively on the 1.2-in. bar. In considering these figures it must, of course, be borne in mind that as specification figures these are all minima. In other words, an iron to meet the top grade in the new specification must have a strength, generally speaking, of 22 tons per sq. in. in order to allow a sufficient factor of safety above the minimum permitted, of 20 tons.

The New Basis

The means by which the strength of a cast iron has been increased so substantially in recent years has been discussed in many Papers presented before the Institute. It is at this stage sufficient to say that the use of improved melting technique coupled with the use of steel additions has been the basis for obtaining irons of close grain and high-duty properties. The use of such irons is generally associated with alloy additions, and especially with nickel, in order to obtain the greater latitude and security given by the addition in counteracting any tendency to hardness on account of the nature of the base iron. The great value of such alloy additions lies in the fact that whilst controlling machinability they maintain at the same time density and pressure-tightness in the thicker parts of the casting, whereas the older method of using silicon led to the production of irons with much narrower latitude, showing, therefore, a much wider variation in structure in different sections.

Inoculation

A further development in the production of high-strength irons has, of course, been the use of the principle of inoculation, whereby types of iron of low silicon content are rendered available for commercial castings by a combination of suitable graphitising effects and inoculation to control the size, form and distribution of the graphite. These inoculated irons as, for example, Ni-Tensyl and Meehanite, are the commonest types employed in meeting the highest grades in the new specification.

Another direction in which real progress has been made in recent years is in the heat-treatment of cast irons. Previously it was realised that heat-treatment, as by quenching and tempering a casting, led generally to failure by cracking, since, in order to obtain effective response from the treatment, quenching from high temperatures in cold water was necessary. A better understanding of the fundamental principles of the metallurgy of cast iron now available and the use of alloy additions have changed all this, so that to-day many types of engineering castings can be improved substantially in hardness and strength by relatively simple and mild heat-treatment procedure.

Wear Resistance

The new tools put in the hands of foundrymen by the use of alloy additions have enabled him to meet many of the more specialised demands of the engineering industry. For example, to-day when castings for resistance to wear are required, the foundryman can offer a straight alloy cast iron such as a nickel or nickel-chromium iron, or one of the grey martensite irons produced by the use of sufficient alloys to give the martensitic structure as cast, or again he can offer one of the mixed-structure irons in which a combination of austenite and martensite gives resistance to wear and abrasion coupled with resistance to corrosion, and furthermore maintains its properties at relatively high temperatures. In other cases improved resistance to wear is obtained by various special types of surface treatment, or again by other special alloy additions.

If faced with the problem of providing corrosion-resistant castings, the foundryman now has the austenitic cast irons to offer if the conditions are severe. If mild, then some of the lower alloy irons may be effective. For special conditions the high-silicon irons or high-chromium irons have proved useful, when their hardness and brittleness are not a disadvantage. For resisting heat, once again a whole series of irons is available, ranging from low alloy irons suitable for firebars and other common castings, up to the highly alloyed types, such as Ni-Resist, Nicrosilal and the high-chromium cast irons.

These examples must be taken as only representing some of the directions in which new types of cast iron are now available as a result of the extensive progress made in recent years. To-day, there are signs that even greater progress will be seen, and metallurgists are already talking of the regular production of castings with a strength of 30 tons per sq. in. In other cases the development of materials of low carbon content and lying on the borderline between cast iron and steel is being actively pursued, and these materials, after heat-treatment, are known to give astonishing results, as in the case of the crankshaft iron mentioned above, which showed a strength of 63 tons per sq. in.

Present Reactions

With all this development before us, it is surprising to find that engineers and designers still frequently calculate safe stresses on the basis of cast iron having an ultimate strength of 5 to 9 tons per sq. in. The position still seems to be, as it was thirty years ago, that technical progress is still in advance of foundry practice as applied in many foundries. This may be due in part to the lack of appreciation by the engineer of the irons now available, but foundrymen should take the initiative. Progress is based, not on waiting for the demand to arise, but in taking active steps to create the demand by offering the best available. Considerable progress has been made in recent times in educating the engineer up to an appreciation of the progress made by the industry. For example, the new specification published in 1938 has already received considerable attention by the engineering profession. One of the most outstanding signs of the time, however, is the setting-up by the Institution of Mechanical Engineers of a committee to study the position of high-duty cast irons to-day, thus indicating a real interest on the part of engineers in recent achievements in the foundry. This committee gave its first report before Christmas, and the reception given to the report and the discussions evoked are indicative of the fact that by closer co-operation with engineers a great future lies before the foundry industry.

Notes from the Branches

Birmingham, Coventry and West Midlands Branch.—A slight increase in membership and a satisfactory financial position were reported at the annual meeting of the Birmingham, Coventry and West Midlands Branch of the Institute of British Foundrymen, held at the James Watt Memorial Institute, Birmingham.

Mr. L. W. Bolton, A.M.I.Mech.E., presided, and in his annual report Mr. A. A. Timmins, A.I.C. (hon. secretary), said that the year under review had been quite a successful one. The membership remained substantially the same as last year. Although 25 new members had been elected, 18 members had either resigned or been transferred to other branches. During the year the Branch had been unfortunate in losing five members through death, amongst them being Mr. W. J. Molineux, who was elected Branch-President only a short time before his death. The total membership now stood at 335.

Six meetings, including the present one, had been held during the year, and Papers dealing with various aspects of foundry work had been considered. One of the lectures was held as a joint meeting with The Institute of Vitreous Enamellers, and dealt with cast iron for vitreous enamelling. There had been a good attendance at all meetings, an average of 52 being obtained for the session. Lively and stimulating discussions followed all the Papers. Only one works visit had been arranged, which attracted some 60 members, but it was hoped to arrange two more works visits during the next few weeks. The annual dinner and dance in January was a highly successful function; there was an attendance of 194 members and ladies, the chief guests being the Principal of the Birmingham Central Technical College (Dr. D. S. Anderson), Mr. and Mrs. J. E. Hurst, Mr. and Mrs. A. Allison, Mr. and Mrs. G. L. Harbach and the secretary and assistant secretary of the Institute. The Branch had had a successful year financially, the subscription income of £458 7s. being higher than last year and a record for the Branch. The balance at the end of the year was £34 7s. 7d., compared with that of the previous year of £34 10s. 9d. The expenditure, however, showed a slight increase, £110 3s., as against £106 2s. for the previous year.

As members were probably aware, the International Foundry Congress in London was taking place in June this year, and following it a number of overseas delegates were visiting the Birmingham Branch on June 18 and 19. The Branch Council had arranged a substantial programme for them, including three works visits, and it was also hoped to arrange a dinner and dance on the evening of June 18. It was with great pleasure he was able to record that a sum of £60 had already been generously subscribed by members of the Council and the Branch for the Conference Fund. Further contributions, however, were urgently needed.

In conclusion, Mr. Timmins thanked the members of the Birmingham Branch Council for their co-operation and assistance during the past year. It had been a particularly strenuous one, and he was greatly indebted to Mr. L. W. Bolton for his help and advice.

The report and accounts having been adopted, the election of officers was then proceeded with, which resulted as follows:—

Branch-President.—Mr. A. Tipper.

Senior Vice-President.—Mr. N. C. Blythe.

Hon. Secretary.—Mr. A. A. Timmins.

Members of Council.—Mr. G. R. Shotton, Mr. J. J. Sheehan, Mr. A. G. Harrison (three years) and Mr. J. Hird (two years).

Delegates to General Council.—Mr. H. J. Roe, Mr. G. T. Lunt and Mr. N. C. Blythe.

Delegates to Technical Council.—Mr. G. R. Shotton and Mr. L. W. Bolton.

Hon. Auditors.—Mr. G. M. Callaghan and Mr. W. L. Johnson.

Foundry and Enamel Practice as Applied to Cast Iron*

By GEORGE M. LOGAN

The object of this Paper is the elucidation of the main principles involved in the production of porcelain enamelled castings. In describing these methods of operation, an endeavour will be made to give briefly the reason for them and the principles underlying them. At the same time, an effort has been made to avoid as far as possible scientific detail with the object of drawing conclusions of interest and value to the foundryman and enameller.

The main sections which will be included are the moulding and enamelling departments. For successful and economical production of the finished articles, there must be free and full co-operation between the two departments; and investigation of faults must be carried out with an open mind, and the deductions drawn and conclusions arrived at must be scientific in principle and practical in method. The persons concerned in the investigations must get the best possible value out of any experiment and experience, whether it is a success or a failure, and they must understand the nature of the experiment and act as a result of it, and apply such means as will make it of permanent value to their experience.

Cupola Raw Materials

Bearing in mind that the castings produced have to be vitreous enamelled, then of first importance is the type and nature of the pig-iron and scrap. It is necessary to know the analysis of these for the control of the composition, chemically and physically, of the castings to be produced. Pig-iron should always be purchased to a specified analysis, and that analysis maintained as far as possible. It is a personal belief that the utilisation of two or three brands of pig-iron is preferable. One of the brands should have a low phosphorus from 0.30 to 0.7 per cent., the others being higher than 0.7 per cent. The silicon should range from 2.5 to 3.2 per cent., whilst the manganese in each case should not exceed 1.0 per cent. The total carbon should be in the region of 3.5 per cent., with the combined carbon in all brands as low as possible, and not exceeding 0.30 per cent. in the highest. For ordinary purposes the following analysis regarded from an all-round point of view should suffice:—Si, 2.6 to 2.75 per cent.; S, as low as possible but not to exceed 0.08 per cent.; P, 0.8 to 1.20; Mn, under 0.8 per cent. (say 0.6 to 0.8 per cent.); C.C, as low as possible; and T.C, 3.35 to 3.50 per cent.

The reason for recommending the use of two or three brands of pig-iron is to keep the analysis of the castings within certain limits, and to increase the strength, if necessary. At the same time, a mixed charge gives, generally speaking, a product of more average quality, by a process of levelling up or down. The bulk of pig-iron as used in the author's foundries for the making of castings suitable for enamelling is of the open, soft variety, and sold by manufacturers graded to the analysis. It is necessary, in order to get the best results, to be familiar with the various constituents of the pig-iron, and to know how they react. It is also a decided help to have a knowledge of fracture, provided that the pigs have been cast in a normal manner. The composition of pig-iron and purchased scrap entering the foundry may vary widely. It is therefore essential to have an analysis of each consignment, so that the composition may be adjusted both chemically and physically to give as far as possible the desired results.

Effect of the Elements

Silicon is important, as it controls indirectly the amount of combined carbon. The higher the silicon up to 3.2 per cent., the more open is the grain, and, everything being normal, the strength decreases. Silicon reduces the capacity of the iron to hold the carbon in the combined state, and expels it to form free graphite, giving a softer and more open iron. Sulphur, on the other hand, counteracts the action of silicon, hardening iron and decreasing the fluidity. It is proportionately much more active than the silicon—approximately ten times greater—and 0.10 per cent. additional silicon has to be allowed for every 0.01 per cent. sulphur expected over the usual percentage. The desire is for this allowance to throw out proportionately more graphite.

Phosphorus increases the fluidity of the metal, lowers the melting point, and gives an extended range of solidification. It has a weakening effect on the iron, causing sponginess due to its being last to solidify on cooling, and its tendency to separate from the metal. Over 0.5 per cent. phosphorus has a weakening effect proportional to the increase, and consequently gives iron less able to resist stress, shock and pressure.

Combined carbon is the principal hardening agent in cast iron. The percentage present in a casting is dependent on the silicon content and rate of cooling, for similar pouring temperatures, and provided external influences such as too wet sand or oxidation in melting do not come into play, there should be no difficulty in regulating the combined carbon by a suitable charge of metal. The aim should always be to keep the combined carbon as low as possible, and if working with pig-iron and scrap high in combined carbon, one cannot expect to get castings with low combined carbon, assuming, of course, the pig-iron and scrap have been normally cast in sand and not chilled moulds. The combined carbon should not exceed 0.4 per cent. in castings ¼ in. thick, but definitely not over 0.45 per cent., as, over this limit, castings will be very liable to warp, and the breakings will increase in the enamelling or annealing processes.

Graphitic carbon in itself does not give softness to the metal; it is present as a mechanical inclusion, and has a weakening effect. It is a weak, soft material, scattered through the stronger mass. The larger the flakes of graphite, the greater the weakness, as the iron might as well be hollow where the graphitic flakes are. The size of the graphite flakes depends on the thickness of the casting, rate of cooling and the amounts of the other elements present. The amount of graphite and combined carbon present must be taken into account when considering what it is wished to attain in the finished castings.

Manganese and sulphur should be considered together, as the harmful sulphur is that portion which has been left after the action of the manganese on it. Manganese tends to produce sound castings, possibly due to its action in retaining dissolved gases in solution, in bringing about a reduction in the temperature of solidification, and preventing the formation of iron sulphide. When its action with the sulphur is spent, hardening takes place.

Preparation of Charges

In making up a charge for castings to be enamelled, it is advisable, but not always possible, to work it without the addition of purchased scrap, owing to price, and, when purchased scrap has to be used, good heavy machine scrap should be employed. Its analysis will probably fall within the following range:—T.C, 3.3 to 3.4; C.C, 0.1 to 0.3; Si, 2 to 2.5; Mn, 0.5 to 1.0; S, up to 0.1; and P, 0.5 to 0.7 per cent. With scrap of such an analysis, good results can be maintained, but it must be closely controlled to see that the quality remains more or less constant, and to ascertain that it is not mixed with scrap such as brake blocks, railway chairs, etc., as this type of scrap varies considerably. Very light scrap, very rusty scrap, or burnt scrap should be entirely avoided. The governing factors for the metal charge are: (1) cost; (2) physical properties in the castings; and (3) to get the desired physical properties from the pig-iron and scrap at the lowest cost.

Coke

The next material to be considered is coke, and this will depend on the nature of the charges and blast. It is alway advisable to work with a good dense coke in the bed, and, if the metal charges are heavy and dense, to work with dense coke throughout. If, however, the charges are light and bulky, a less dense coke can be safely used. The coke employed should in all cases be strong physically, and should be low in ash, water, volatile matter and volatile sulphur, and the cellular structure should be regular. The bed coke must be strong enough to support the charges without breaking down, and it must be maintained at a constant height during the melting operations. It can be taken, therefore, that the physical and mechanical properties are of first importance. Using soft coke of open cellular structure, combustion takes place over a comparatively large area with a consequent increase in the melting zone, and the added risk of combustion taking place higher up, above the proper melting zone, giving more resistance to the blast.

Limestone

Limestone in a proportion of 25 to 30 per cent. weight of coke charge is the flux most commonly used, and it should contain in the region of 95 per cent. calcium carbonate. It reacts with the ash from the coke and sand from the pig-iron to form slag which should be from green to brown in colour and have a glassy appearance. If it is black in colour it indicates a high iron content, due to the oxidation of the iron or too little

* Paper presented to a joint meeting of the Scottish Section of the Institute of Vitreous Enamellers and the Falkirk Section of the Institute of British Foundrymen, Mr. R. R. Shaw presiding.

limestone. It is advisable to have the slag reasonably high in lime and fluid in nature, as a slag of this kind will take up correspondingly more sulphur from the charges. It should contain in the region of 30 per cent. lime and magnesia. The silica content should not exceed 45 per cent., while the iron oxide should not exceed 6 to 8 per cent., nor manganese oxide 4 to 5 per cent. The slag analysis should approximate:—Silica (SiO_2), 45; iron oxide (FeO), 6 to 8; manganese oxide (MnO), 4 to 5; lime and magnesia (CaO and MgO), 30 to 35; alumina (Al_2O_3), 9 per cent.

The efficient working of the cupola can in a measure be judged by the analysis and appearance of the slag. Should any of the materials being charged into the cupola be unusually high in sulphur, the limestone should be increased so that the desulphurising action may be increased. With an iron oxide content considerably over 6 to 8 per cent. and manganese oxide over 5 per cent., there is taking place in the cupola excessive oxidation, assuming, of course, that very rusty scrap has not been used in the charge, and that the ash from the coke is of normal analysis. The amount of slag produced varies, but, on an average, it is about 1 cwt. per ton of metal melted.

The Cupola

Much could be said in connection with different types of cupolas, but observations will be confined to control as applied to cupolas generally. The process of operation is a remelting of the pig-iron and scrap, using coke for the fuel and limestone or other flux to form the slag, and the main points for its control and working are (*a*) internal shape and arrangement of hearth; (*b*) the fuel employed, and (*c*) the method of introducing the air. The melting rate is largely controlled by the internal diameter, and it can be taken that approximately 24 lbs. of metal can be melted per minute for each square foot of the area of the cross-section in an ordinary cupola. In cupolas up to about 36 in. dia., the total tuyere area should be approximately one-quarter to one-fifth of the area of the cross-section, and for large cupolas approximately $\frac{1}{6}$ to $\frac{1}{8}$.

In large furnaces, a higher blast pressure is required so that the necessary amount of air can penetrate to the centre, and consequently a smaller tuyere ratio is required. The melting zone of the cupola, with one row of tuyeres, should be confined to as concentrated an area as possible in order to get the maximum combustion and temperature in as small a space as possible. This can be judged by the height of the scouring action just above the tuyeres. A high blast pressure will give an increased melting zone, whereas a low blast pressure will reduce it. This also applies to variation in the air supply, and the greater this variation, the more irregular will be the working and the less dependable the results.

When charging the cupola, each successive charge of metal should be completely covered by coke and arranged basin-shaped so that the air will blow directly on coke and not on metal, to prevent as far as possible oxidation of the metal. A central column of metal or coke should be avoided in order that the physical properties of the metal may be preserved, and the maximum thermal efficiency obtained.

Boshed cupolas require less coke in the bed, but there is a greater tendency to cause bridging, although there is less tendency to cause oxidation of the metal due to the air blowing more on the coke and less on the metal. Drop-bottom cupolas have the advantage that, as soon as the required amount of metal has been melted and run off, the bottom can be dropped and fuel saved by withdrawing any unmelted iron, and by giving more rapid cooling so that the cupola can be repaired for the following day. With a fixed-bottom cupola, any excess metal has to be melted and it is more difficult and harder work to clean out. With the drop-bottom cupola, the disadvantage is that care has to be exercised in making up the sand bed.

The charging door should be as high as possible, and should be about five or six times the internal diameter of the cupola at the tuyeres for a small cupola, and four times the diameter for a large cupola. The object is to pre-heat the charges as much as possible, and reduce as far as possible the temperature of the escaping gases. The higher the cupola, the greater the natural draught, and the quantity of sparks emitted is reduced. The depth of the well of the cupola is controlled by the tuyere height, and depends on the class of work and the quantity of metal required at each tapping. For light work, there is no need to have a high tuyere level, but for heavy work, when greater storage capacity is required, the tuyere level must be higher, or a receiver installed.

Introducing the Air

The shape and arrangement of the tuyeres play an important part in the melting efficiency, and they should be so arranged as to give even distribution of the blast with as low a resistance as possible, and should be proportional to the cross-section of the cupola at the melting zone. The aim is to get the maximum of heat from the coke in the minimum of space, and to obtain quick and hot melting. Therefore, the quantity of air has to be regulated so that the carbon of the coke is burnt to CO_2 and thereby gives out the maximum amount of heat. In addition, the heat evolved must be usefully employed in heating, melting and superheating the metal and slag to the desired temperature.

With too little air or too much coke, incomplete combustion takes place; but, if too much air is admitted, or too high a blast pressure used, the products of combustion are swept away before doing their useful work, and in both cases extravagance in fuel results. In the second case, where there is an excessive amount of air admitted, oxidation of the metal will take place, and the castings produced will be low in total carbon and high in combined carbon. For good cupola operation, it is necessary to have good thermal efficiency, or, in other words, the amount of heat generated from the fuel is usefully employed in melting and superheating the metal. The main loss of heat is in the exhaust gases from the cupola, so that the escaping gases should be as low as possible in temperature and high in carbon dioxide. The maximum amount of heat should be extracted from the escaping gases from the cupola, and there should be sufficient height between the melting zone and the charging door to do this.

The main functions of the cupola are to melt the charges so that the properties aimed at by the introduction of the various brands of pig are not destroyed and that the molten metal being delivered is suitable for enamelling. This is best obtained by quick and hot melting, which is in turn dependent on correct height of the bed, correct weight of charge and coke, maintenance of the height of the bed, the right quantity of air, and good fluid slagging. The iron produced should be soft and low in combined carbon so that castings will not readily warp or cause undue breakage.

It is desirable to have freeness from porosity, and for this purpose there should be sufficient manganese—approximately 0.6 to 0.7 per cent. is about correct. It should have 3.35 to 3.5 per cent. total carbon, and the combined carbon not over 0.45 per cent. It should be run from the cupola, well superheated, but not cast at a low temperature; and the heat should not fall away rapidly. If this does happen, there is invariably bad melting practice and very probably oxidation, which can be found by analysis, for the total carbon will be low, combined carbon high, and silicon and manganese below the calculated amounts.

The moulds for castings to be enamelled should be well rammed, not too hard and not too soft. A fair gauge of satisfactory ramming is the amount of excess weight of the castings over the pattern weights, and this can be placed in the region of 10 per cent., but should not exceed 12 per cent. When softly rammed, the result shows up badly on the enamelled castings, and especially if the castings have perpendicular sides, or are placed upright, in which case the enamelled surface will appear rough or lumpy. Very often the enameller gets the blame for this, whereas it is the moulder who is at fault.

Sand

The sand used for moulding embraces the properties of refractoriness, permeability, bond, fineness, facings and moisture. Refractoriness is controlled by the silica content and freedom from alkalis, lime and magnesia, and should be such as to enable the sand to resist fusing on to the surface of the casting. The sand must also possess sufficient permeability when properly rammed to allow the gases to escape with freedom when the molten metal comes into contact with the mould face. Hence the grain shape, size, and bond will have a very definite bearing on the freeness to vent. Coupled with this is the pouring temperature, which, if too high, will be liable to cause the sand to burn into the casting, and will cause excessive washing away at the gates, producing small cavities in or just under the surface.

Too much moisture will cause surface chilling and internal shrinkage, with accompanying high breakage and warpage. The finish of the mould and the type of facing used depend to some extent on the after-treatment of the castings. If they have to be shot-blasted, a variety of facings may be used successfully, but in all cases facings should be used sparingly and should be infusible in nature. Shot-blasting has the disadvantage of bringing out all the surface defects, or those just under the surface, but it is essential if the castings have to be enamelled by the wet process.

Surface Finishing

It is advisable, though not essential, when enamelling by the dusting process, to shot-blast. If the castings are not shot-blasted, they must be thoroughly scoured with sandstone, or emery stone, and in this operation much more care must be taken, and rigid control exercised over the iron and enamel composition. This method has the advantage that defects just under the surface are not exposed, and, generally speaking, a smoother finish is obtained. It has, however, the disadvantage of poor adhesion with a consequent liability to damage from shock, and any gain in appearance is more than offset by the poor adhesion and the narrow limits within which one has to work to avoid such troubles as chipping and crazing. It is necessary to avoid facing materials such as plumbago, quartz, etc., as these materials are not entirely removed by scouring, and bad adhesion results.

Storage of Castings

The castings, prior to enamelling, should be stored in a dry warm atmosphere to prevent rusting or oxidation of the iron. Castings stored in a cold, damp warehouse, though not showing evidence of rust to the naked eye, will immediately reveal this condition in the enamelling process by boiling through the enamel. It is always advisable, especially in wet-process work, to anneal and shot-blast with as little delay as possible, and thereafter enamel the castings within the next twelve hours. If castings must be held over till the next day after blasting, they should be kept in the drying room.

With castings to be enamelled by the dusting process, very dry storage and annealing of the castings are not necessary, provided the castings have not been stored for too long a period. It is quite possible to enamel successfully such articles as baths without annealing which have been in store for a week or two, provided they get a good blasting. The reason is that such castings get a thin ground coat

and although blistering of the ground coat may take place, it can be eliminated before the dusting operation is commenced. Even shot-blasting is not essential, although it is advisable, for some classes of dusting enamels, and in cases of this kind the boiling or blistering which takes place in the burning-in of the ground coat is even more pronounced, but can be eliminated by withdrawing the articles from the furnace for a second or two, when at the maturing point of the ground coat. The process requires very rigid control as it is dependent to a large extent on the skill of the worker, and on the exact composition of the enamel and iron.

Shot-Blasting

The amount and nature of the shot-blast operations will depend on the process of enamelling (whether by wet or dry), the hardness of the surface of the casting, the shape of the castings, and the efficiency of the shot-blast plant. For dry-process work a great deal of blasting is not necessary, and a pressure of 30 lbs. is quite suitable; the air employed need not be dried, provided the castings are enamelled within 12 to 24 hours after blasting. For wet-process work, it is esential that oil and water be kept out of the air supply, and for this purpose an after-cooler should be used. It is customary for wet-process work to operate with an air pressure of 60 to 80 lbs.; lower pressure can be used quite successfully, though the blasting operations will require a longer period.

Using steel grit as an abrasive, the higher the blast pressure and the softer the surface of the metal, the greater is the tendency to expose metal or moulding defects, such as surface cavities, or cavities just beneath the surface. These troubles can very largely be traced to the moulder, and are due to a variety of causes such as too moist a sand, hard ramming, loose or weak sand and mould facings. Many of the castings for enamelling have thick and thin sections, bosses, flanges, ribs, etc., and after blasting it is found that at the junction of the different thicknesses of the metal spongy areas have been exposed. The cause may be incorrect gating, unsuitable composition, or metal which is too hot, and the remedy is to alter the system of gating in the first case, reduce the silicon and phosphorus of the metal in the second case, or cast at a lower temperature in the third case.

After the blasting treatment, all castings should be thoroughly examined by a competent person, and those with more than the average amount of defects should be rejected. The standard of quality will depend on the process of enamelling, whether wet or dry. For the wet process, a much higher standard is required—by which is meant greater freedom from surface defects—as the thickness of the enamel on the finished articles will be thinner, and they are subjected from one to three firings. In all cases, cavities should be filled in with a good fire cement prior to enamelling or ground-coating, and sufficient time must be allowed for the thorough drying of the cement; otherwise, on heating in the muffle furnace, the cement will be thrown out, exposing the cavity and perhaps precipitating itself on another part of the enamelled surface.

(To be continued.)

Vitreous Enamel and its Interest to the Gas Industry*

By W. J. HARRIS and J. GREY

The gas industry is interested in this subject from two aspects:—First, as a result of the recent wide application of vitreous enamel to gas appliances; and secondly, because gas as a fuel has made great strides in this branch of industry and there is in the enamelling industry still a wide field for the application of gas as a fuel.

An early application of vitreous enamel to gas apparatus was the enamelling of steel linings of gas cookers, and then the loose steel crown-plates and plate-rack backs. An endeavour was made by some manufacturers about 1912 to introduce vitreous enamelled cast-iron gas-fires, but these did not become popular with the public. At that time the enamelling of cast iron was carried out by the "dry process."

The introduction of the wet process of enamelling on cast iron in the year 1925 marked the beginning of a new era in the production of enamelled gas-appliances. This process was, to a considerable extent, made possible when the manufacturers discovered they could make an enamel which could be applied direct to cast iron, after thoroughly cleaning the surface of the casting by shot-blasting.

Some of the grey mottle finishes can be completed in one firing, but white and light colour work requires from two to three coats. In this case the first coat is fired, the castings are allowed to cool, and returned for re-spraying, dried, and fired. It will be seen that the mottle finish is usually a thinner coat of enamel than the colour work and consequently is less likely to chip and has greater adhesion powers; hence its popularity. This is important to the gas industry from the maintenance point of view. Black and dark colours require fewer coats than white and light shades and therefore have the same advantage as the mottle finishes.

The manufacture of vitreous enamel is a highly specialised process, but broadly speaking, vitreous enamel is a glass made from a complicated formula, and the following constituents are used in various enamels:—Quartz, felspar, borax, fluorspar, soda ash, cryolite, zinc oxide, cobalt oxide, and antimony oxide. Other chemicals are also added in varying proportions. After describing the preparation of frits, a typical milling formula for a sheet iron enamel was given:—100 lbs. sheet iron white frit; 5 lbs. enameller's clay; 4 lbs. tin oxide, and 38 lbs. water.

The application of enamel to sheet iron parts of gas apparatus was greatly extended at the same time as the introduction of the wet process on cast iron, although the wet process of enamelling of sheet iron was an established practice for many years before that date. It is simply that the introduction of the wet process of enamelling on cast iron had an energising effect on sheet iron enamelling.

It is hardly necessary to mention the great advantage that the extensive application of vitreous enamel to gas appliances has to the consumer, as it possesses the qualities of durability and ease of cleaning, making the apparatus more hygienic and giving it a lasting attractive appearance. Vitreous enamel enables the kitchen equipment, including the gas cooker, gas refrigerator, coke boiler, and gas water heater, etc., to be finished in shades to tone with any desired colour scheme.

Gas Fuel for Vitreous Enamel

The application of gas as a fuel to the enamelling industry from the point of view of its efficiency compared with other fuels, and the design of furnaces, was very thoroughly dealt with in a Paper given by Mr. W. Dieterichs, before the Institute of Vitreous Enamellers, in the early part of 1936, but a reference to this very important aspect of the matter will be of general interest.

The first stage in the enamelling process where fuel is used is the smelting of the frit. The oldest frit smelters were of the coal-fired reverberatory type, similar in design and operation to the glass-smelting tank. Oil fuel was later employed for the operation. Only in a very limited number of cases has town's gas been used for this operation. This is due chiefly to the fact that highly oxidising atmospheres have to be maintained, which results in excessive heat loss by way of the flues, and so far it has not been found practicable to incorporate recuperators or regenerators in this type of furnace. There is little doubt, however, that the attention which is being directed to this matter will result in a solution being found to this difficulty.

The firing of the muffle furnace for fusing the enamel, by town's gas, is a well-established practice, but there is still a large potential market available in this direction. The extent of the possibilities will be better appreciated when it is realised that in the enamelling industry throughout Great Britain there are approximately 500 of the muffle furnaces in use, and of these only about 15 are town's gas-fired.

The average gas consumption of an enamelling muffle furnace can be taken as 2,000 cub. ft. per hour. This is a 24-hour day operation, the furnace running an average of six days a week for approximately 50 weeks in the year, and assuming that only 50 per cent. of these 500 furnaces were gas-fired it would mean a consumption of 3,600,000,000 cub. ft. of gas per annum.

For drying the enamels between the various operations there is a variety of types of ovens used throughout the enamelling industry, including the box or square-oven type, horizontal and vertical conveyor types. A percentage of these are heated by gas, using direct heat or independent gas-fired air heaters, but there still remains a great opportunity for gas in this field.

Gas can also be extensively used for the heating of a number of tanks in the pickling room and for the special drying ovens which are included in the pickling room equipment. It can be taken that the gas consumption for the auxiliary equipment is approximately 500 cub. ft. of gas per hour per fusing furnace.

Referring to the figures already given, and assuming that only 50 per cent. of these were gas-fired, this would mean a total gas consumption of 900,000,000 cub. ft. per annum. This, added to the figure already quoted, gives a grand total of 4,500,000,000 cub. ft. of gas a year. The magnitude of this potential gas consumption will be better realised when it is considered that it is equal to about two-thirds of the total gas distributed by the Manchester Corporation Gas Department annually.

A recent introduction to the enamelling industry is a method of de-enamelling, and probably the limited number of plants of this type which have so far been installed are all heated by gas. Therefore, as this operation becomes more widely used, a further potential use for gas presents itself.

* Extract from a Paper read to the British Commercial Gas Association.

The Control of Enamels*

By A. J. D. BLACK

In enamelling, particularly by the dry process, the local conditions in each plant vary from those existing in other plants, and as a consequence the interpretation of results is open to different readings according to different observers. This is one of the difficulties which arise in arriving at the true meaning of some of the occurrences which are of everyday happening in enamelling plants. It also follows that different men have formed quite different views on the common experiences in enamelling shops, and it is likely that some may not agree with all of the opinions put forward.

It is not proposed to discuss the composition of the enamel, and it will be assumed that the frit is correctly compounded; that is, that an enamel frit has been produced with the proper expansion in relation to the metal base in use, and of suitable colour and opacity for the purpose for which it is intended. Although the remarks will be chiefly applicable to dry-process enamelling, the same methods will in most cases be applicable to wet-process enamelling of cast

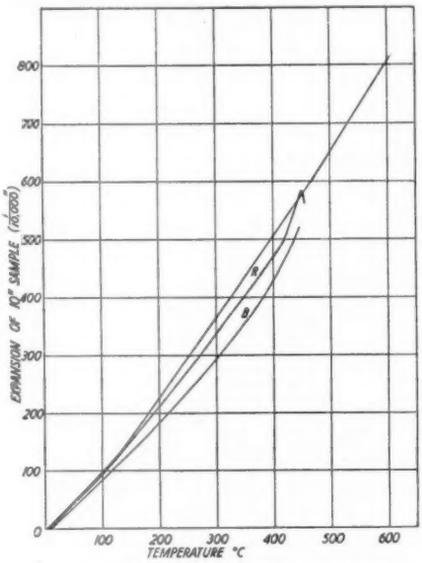


FIG. 1.—CURVES OF IRON EXPANSION COMPARED WITH LEADLESS ENAMELS.

iron or of sheets. In a few cases where there are points of special difference between the two methods, brief reference will be made.

Control of enamels may well be said to commence with the purchase of raw materials of suitable quality for the manufacture of first-class frits. Savings obtained by using cheap materials may very easily result in loss of product or in loss of quality of product, and in either case the losses may greatly outweigh any saving in prime cost. The purchase of high-grade material is the only safe course, and is the general practice to-day with all manufacturers of repute.

Constancy of composition of the materials is essential, and analyses of the batches received as they come to hand are desirable. This is particularly the case with felspar, which may vary considerably in composition in succeeding batches even from the same mine. The refractory materials (quartz and felspar) must also be carefully checked as regards their state of division. It is important that they should be sufficiently finely ground. If this be not the case, then they may not be dissolved in the molten fluxes during the melting process, and in this event a heterogeneous product is turned out when the melt is quenched, and loss of quality is the result.

Weighing and Mixing

It is unnecessary to stress the need for accurate weighing of the raw batch, as without this desideratum all other control methods are useless.

A very thorough mixing of the raw batch also is essential, and it is almost impossible to mix the batch sufficiently well without the use of machinery. A large variety of machines is on the market, but an ordinary ball mill is quite satisfactory and has the advantage of grinding down any small lumps of crystalline materials in addition to very thorough mixing. A material such as borax or saltpetre which has become lumpy in storage is therefore broken down to fine particles, and these are mixed in the batch, whereas, with paddle or agitator type mixers, this breaking-down of lumpy materials is by no means certain.

Melting

The control of the melting operation will vary according to the composition of the batch and in general is by no means sufficiently well done. Control is much more difficult with coal-fired melters than in furnaces using the more expensive fuels, which allow for considerably greater accuracy in the heat-treatment of the enamel.

The temperature of the melter should be adjusted in such a manner that the frit is melted to a homogeneous mass with the minimum of loss of the volatile opacifiers. The exact technique for any given batch will vary according to the composition of the batch, but usually it can be said that the best method is to start melting with as hot a furnace as possible, and gradually to reduce the temperature as the melting process proceeds so that only a safe temperature exists in the melter towards the end of the melting process, to permit of proper "fining" of the batch without undue loss of opacity.

Without good "fining" or in other words proper solution of the refractory quartz and felspar particles in the more readily melted fluxes, the quality of the enamel must of necessity be poor. This applies both to appearance and to wearing qualities.

Milling

The grinding of enamels for dry-process work is a point on which opinions vary. Some authorities state that grinding should be kept definitely coarse-grained to save loss from fine dust, which blows away during the dusting process. This practice is not the method favoured by most enamellers, as they prefer their enamel fairly fine, chiefly because it is easier to control the flow of it from the duster, and also because there is less tendency for the enamel to slide down into the bottom of the bath during application. The coarse-ground enamel is very liable to produce faulty ware due to running down in the corners and scoop end of a bath, and because of this is usually worked under protest. The usual grinding which is followed in most plants can be taken as about 85 per cent. through 200-mesh I.M.M. standard sieve.

For dry enamelling of small articles by the dipping or rolling method, coarser grinding is better and gives a more regular coat of enamel.

In wet-process enamelling of cast iron, control of fineness of grinding is of prime importance if consistent results are to be expected. The exact figure at which to work depends on the composition of the actual enamel used and to some extent on the type of the work in hand. It is, however, definitely necessary to do regular tests on each mill batch before emptying the mill, to ensure maintaining the fineness within the predetermined limits which will ensure the desired results.

If the enamel is too coarse, it will present difficulties in application, and may even prove unable to flow evenly through the spray gun. If it is too finely ground, it will be found to have a great tendency to develop crawling during the fusing process. Enamels all appear to have an optimum fineness for producing good work, and this also appears to vary in different works for the same frit according to local conditions. It follows therefore that each enameller must determine the correct grinding for his own conditions and then maintain his ground enamel at the correct fineness for his work.

In the running of a ball mill, work is done in raising the porcelain balls and allowing them to fall as the mill revolves, and not all of this work is used up in grinding down the enamel particles. It follows that this amount of unabsorbed work shows its presence as heat, and the mill itself heats up considerably during the grinding of a batch of frit. In dry-process work, this heating-up of the mill has no effect on the enamel produced, but in wet-process work this state of affairs does not maintain. It will be easy to

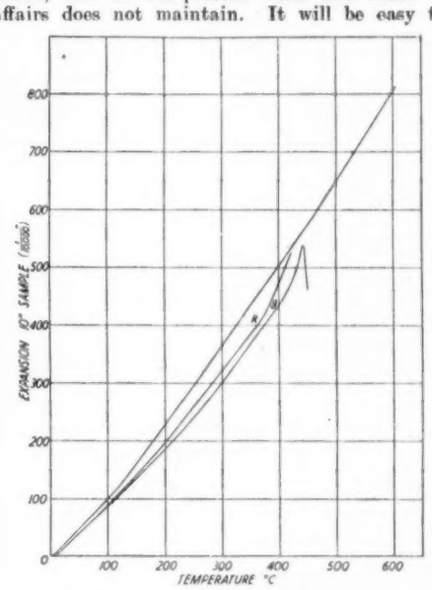


FIG. 2.—CURVES OF IRON EXPANSION COMPARED WITH LEAD ENAMELS.

appreciate that by varying the speed or the weight of the total mill charge, or of the proportions of frit to grinding stones in the mill charge, it is possible to aggravate or to lessen the amount of heating developed in milling a charge.

If the conditions are such that considerable heat is produced, it will be found that the enamel will most likely show difficulty in floating. This is due to the hot mill liquor causing excessive solution of the soluble salts in the enamel, with resultant deflocculation of the clay and settling of the slip. In grinding wet-process enamels, it is necessary to vary the speed of the mill or the loading of the mill to get running conditions which will give the minimum rise of temperature during grinding. In America, in the hotter parts of the country, it is necessary to use water-jacketed mills to keep the mill charge cool enough in the summer months, but this is not necessary in Britain, provided care is taken to avoid as far as is practicable rise of temperature.

It is usual also in wet-process work to control the consistency of the ground enamel. This may be done by a simple type of viscometer, water being added to bring the consistency of

* Paper read before the Scottish Section of the Institute of Vitreous Enamellers.

the enamel down to a predetermined figure. This figure also is one which depends on local conditions, and each enameller has to determine for his own work and conditions what the figure should be, and then by regular checking to maintain the supply of enamel to the sprayers at this consistent figure.

"Fit" of Enamel to Metal

The commonest cause of loss with dry-process enamelling is that due to error in "fit" of the enamel to the metal base. The metal expands on heating and contracts on cooling, and the enamel must have a coefficient of expansion which has a definite relationship to that of the iron or failure will result. Until recently, the only control possible consisted in waiting and watching for either crazing or chipping to occur and then to make the necessary adjustment in the enamel raw-material batch to correct whichever fault had arisen. This method meant delay, as the fault had to manifest itself on the ware before any step could be taken, and then the corrected enamel had to be made before work could proceed.

In some cases the enameller might be fortunate to find some particular pattern which, because of sharper curvature or some similar peculiarity, showed the trouble sooner than the other patterns, and he would be able to utilise this pattern as an indicator of impending trouble.

Fortunately for enamellers of these days, the bulk of the enamels in use were of an easily fusible type with considerable elasticity, and they had quite a considerable tolerance of "fit" between chipping and crazing; thus a reasonable proportion of good work could be produced even with no better method of control than the "hit and miss" method.

With the public demand for enamels of higher resistance, a much harder type of enamel has been developed and is now in fairly general use, and it has been found that consequent on this change the latitude of "fit" between chipping and crazing has been very considerably reduced.

As a result, very serious loss from chipping or crazing has been encountered from time to time, and it has been found very difficult to keep within the narrow limits of tolerance to avoid these faults.

In addition to this, further trouble arose with these enamels. The fault might not develop for a very considerable time after the enamelling process, and in all probability would only be seen after the bath had been built-in with expensive tiling. It is obvious that, under present-day conditions, if a plant is to be run successfully, some method of controlling the expansion of the enamel is almost an essential, and in any case, it adds very materially to the peace of mind of the management.

It must be pointed out quite clearly that all crazing or chipping is not due to errors in expansion of the enamel. Either fault may be due to faulty or badly-designed patterns producing unevenly sectioned castings, and chipping may also be due to unsuitable or improperly applied ground coat. In such cases the skill of the enameller must be such that he can diagnose the trouble and arrange for the removal of the cause. In practice, however, it is very seldom indeed that any doubt arises as to the cause of a case of chipping or crazing.

Testing Methods

The method of carrying out the test is a subject that warrants careful consideration. Reference books will show that there are two distinct methods available. In the first, small specially-prepared and annealed pieces of enamel or iron are placed between the two optically prepared discs of an instrument known as an "interferometer," and the pieces adjusted to show interference rings in an eyepiece positioned for keeping the interferometer discs under observation. The movement of the interference rings when the samples are heated gives a method of calculating the expansion of the samples.

The method is one of high accuracy, but its carrying out is one demanding a high standard of technical skill, and it is therefore purely a method for use in a research laboratory and is hardly suitable for works' use, where something simpler and more robust is an essential, and reasonable accuracy is sufficient.

The advantages of the interferometer are its accuracy and the use of small samples which can be easily heated evenly throughout, and which are more easily prepared than the larger samples used for the direct expansion method.

Direct-Expansion Test

The direct-expansion method consists in preparing a sample of the enamel or iron in the form of a rod and heating this under conditions which allow for uniform (or as nearly uniform as possible) heating and also providing some means of measuring the increase in length corresponding to a measured increase in temperature.

The longer the test rod is, the greater the deflection available and the greater the accuracy of the measurement, but this is counterbalanced to some extent by the increased difficulty in preparing the sample and in ensuring it is evenly heated. It is obvious, therefore, that a compromise is necessary, and local considerations will probably have to be taken into account in deciding on the best equipment for any particular plant.

From personal experience, the author has found no difficulty in preparing rods of enamel 10 in. long, and with a little practice anyone can do the same. This length of rod gives a deflection which can be directly measured on a sensitive dial gauge, making an easily-worked apparatus. Iron test-pieces can also be prepared to test in the same apparatus.

The British Cast Iron Research Association employ a direct-expansion method, but use a sample 2 in. long by ¼ in. diameter, bored through with an ⅛-in. hole. This allows for great accuracy in heating, and as the thermocouple is actually inside the sample, there is no lag in the temperature readings which always occurs with the enamel samples which cannot be so conveniently formed with the central bore for the pyrometer. The small expansion of the 2-in. sample is measured by means of a Cathetometer, and the method generally is ideal for the examination of metal samples.

The apparatus in use by the Bureau of Standards in America makes use of a sample 20 cms. (just under 8 in. long), and with this longer sample the expansion is measured by means of a dial gauge.*

The author's apparatus is of similar type to the Bureau of Standards equipment, but has been arranged for a sample length of 10 in. The expansion is measured on a dial gauge graduated in divisions, each of which represents one ten-thousandth of an inch. This gives ample accuracy for the works requirements and makes a fairly robust job. The sample under examination is contained in a fused silica tube, closed at one end, and the expansion of the sample is transmitted to the dial by the movement of a fused-silica rod sliding within the tube. The resultant reading on the dial is the expansion of the sample less the expansion of the silica tube in which it is contained. The expansion of fused silica is small and is fairly well established. The Bureau of Standards have published a Paper on the expansion of vitreous silica and their results can be taken as correct. It is therefore necessary to correct the direct readings of the apparatus by adding 5×10^{-7} for every 100 deg. C. through which the sample is raised.

The measurement of the temperature at first occasioned some difficulty, but the final arrangement was to use surface-type thermocouples clamped on the outside of the silica tube, and in this way the operator is able to measure accurately the temperature of the silica tube. This still leaves a small temperature lag between the tube and the sample, but by manipulation of the heating controls of the electric heating furnace it is possible to allow this difference to disappear before taking the readings, and used in this way the results are comparable with those obtained by other investigators.

In a recent Paper† on thermal expansions of some enamel frits written by Harrison, Swéo and Shelton, comparison of the interferometer and the direct-expansion methods is made. The following is a summary of the findings:—

> "Consistent difference of about 3 per cent. was observed between the expansivities from 25 to 400 deg. C. as determined with the interferometer using specimen 5 mm. tall and 3 mm. diameter, and those determined with quartz tube and indicating-dial apparatus using specimens 8 in. long and ⅜-in. cross section. Interferometer specimens cut from the larger specimen gave the same difference in results, a difference inherent in the methods of test. Smaller specimens better adapted to continuous determination."

The expansion of the base metal varies considerably, and although much investigation has been done on the subject, very little of it applies to iron of a type suitable for enamelling, and the results therefore are of little assistance to the enameller. In a Symposium on Cast Iron of the A.S.T.M. referred to in Volume 2 of his book on "The Alloys of Iron and Carbon," by F. T. Sisco, a number of figures are given. The range of variation of expansion coefficients (linear) from room temperature to 1,070 deg. C. is stated to be from 92×10^{-7} to 169×10^{-7} which represents cubical coefficients of 276×10^{-7} to 507×10^{-7}.

Sirovich and Vanzetti give the thermal expansion from room temperature to 400 deg. C. of iron containing 3.0 to 3.6 per cent. total carbon and 2.05 to 2.35 per cent. of silicon; sulphur 0.07 to 0.15 per cent., manganese 0.55 to 0.80 per cent., and phosphorus 0.6 to 1.0 per cent. Seven samples were examined in which the combined carbon varied from 0.50 to 0.67 per cent., and the thermal expansion (linear) varied from 125×10^{-7} to 128×10^{-7}. One iron was examined with 3.45 per cent. total carbon and 0.350 per cent. combined carbon, and with 0.59 per cent. each of manganese and phosphorus, and it gave an expansion of 123×10^{-7}. It was therefore concluded that a low combined carbon gave a low coefficient of expansion. These figures converted to cubic expansion coefficients are 375 to 384×10^{-7}, and for the low combined carbon sample 369×10^{-7}. These last figures incidentally compare favourably with those obtained in personal tests.

Veilhaber, the German enamelling consultant, has done considerable work on this subject. In an article in "Emailawaren Industrie," published in 1932, he quotes figures given by an American, Kent, on a method of calculating the expansion from the composition, which is given briefly herewith:—

Total carbon	0.00001311
Silicon	0.00001272
Manganese	0.00003015
Phosphorus	0.00020883
Sulphur	0.00019668
Iron	0.00001709

As in the case of enamel expansion calculations, the percentages of the elements present are multiplied by these factors and the resulting figures added together to give a sum S. This is then multiplied by the temperature (deg. Fah.) concerned and by 100.

* Bureau of Standards Journal of Research, 1928, 1, p. 771.

† Bureau of Standards Journal of Research, 22, No. 2, p. 130.

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Veilhaber gives one iron as an example and is quoted as follows—:

C ..	.. 3.7	× 0.00001311	= 0.000048507
Si ..	.. 1.9	× 0.00001272	= 0.000024168
S ..	.. 0.115	× 0.00019668	= 0.000022618
Mn ..	.. 0.48	× 0.00003015	= 0.000014472
P ..	.. 0.60	× 0.00020883	= 0.000125298
Fe ..	.. 93.21	× 0.00001709	= 0.001592959
			0.001828022

For a temperature of 900 deg. C. one obtains from this iron:—

Expansion = S × T × 1.87 × 100 (1.87 is factor for converting deg. C. to deg. Fah., but is wrong; should be 1.80).
= 0.001828 × 900 ×187.
= 307.6.

He compares results obtained from a number of calculations using this method with other results, using a method of his own which will be described later in this Paper, and shows that this method gives very slight differences in expansion over a wide range of compositions. It is also very difficult to see what the 900 deg. C. has to do with the expansion coefficient, but the method is of interest, as, if similar factors could be got to connect composition with expansion, it would be of value to the enameller.

It is quite obvious that any method of calculating the expansion of cast iron from its analysis must neglect one prolific source of variation, namely, the foundry practice. Veilhaber indicates this and only claims comparable figures with his method if all the variables are standardised. He points out that thin parts in a casting will have a higher coefficient of expansion than thick parts, that castings rapidly stripped will have a greater expansion than the same castings allowed to cool in the sand mould. Similarly the use of green sand will bring about a higher expansion than that obtained with the same metal in a dry sand mould.

Veilhaber's estimate of the expansion of a cast iron as given in his booklet "Die Emaille ihre Zusammensetzung und Eigenschaften" is as follows: He correlates the expansion with the silicon content as follows:—

Silicon, per cent. ..	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6
Expansion ..	421	414	407	400	393	386	379	372	365	358	350	342	336	327	318	309

This table gives values for iron with no manganese and with 0.08 per cent. sulphur. For each 0.01 per cent. sulphur over 0.08 per cent., a deduction of 0.1 is made in the silicon and conversely. The expansion figure is further increased by 1 point for each 0.1 per cent. of manganese.

Unfortunately neither of these methods gives results which compare at all consistently with actual determinations of expansion, but they are mentioned as the only work available along this line.

Most enamellers have very limited opportunities for an investigation of such a subject. In most cases, the variety of irons is very small and only by gathering figures over a wide variety of analyses and in very considerable numbers could one hope to arrive at any basis for approach to a formula.

The author is indebted to Mr. Deurvorst, of Ferro-Enamelling Company, Holland, for the data embodied in Table I, which gives the expansion determined by his concern for nine different irons. The silicon varies from 1.96 to 2.80, phosphorus 0.41 to 1.47; manganese 0.32 to 0.76; sulphur 0.049 to 0.126; total carbon 3.23 to 3.70; graphite 2.57 to 3.43, and combined carbon 0.07 to 0.66 per cent., and the expansion coefficients vary from 358 to 379 × 10^{-7}. Graphing the actual analysis against the expansion fails to show any connection for any single component.

Table I is valuable in that it covers a much wider range of composition than is found in ordinary everyday work in any one works. It will be observed that a considerable variation in the expansion of the iron occurs and that there is no obvious connection between the composition and the resultant expansion. The variation noted is from 358 × 10^{-7} to 379 × 10^{-7}, and this is more than enough to cover the range of latitude available between chipping and crazing.

The iron now being used by the author has the following analysis:—Si, 2.77; Mn, 0.55; S, 0.08; and P, 1.07 per cent., which shows an expansion of 365 × 10^{-7} on an annealed sample. The expansion curve of this iron, as compared with curves for enamel which works on it, are indicated in Figs. 1 and 2. It will be seen that up to 600 deg. C. the expansion of cast iron is almost linear, and it has been found that in cooling from this temperature it contracts along the same line.

Samples of this iron have been examined by the British Cast Iron Research Association, and their results are very interesting. They show that on the initial heating of an unannealed sample an expansion was obtained which was materially less than that obtained on a succeeding heating, and that this increase continued up to the third heating to 930 deg. C. The results are set out in Table II.

A second specimen gave results confirming Table II. A second test was done on an annealed sample of similar analysis, but containing slightly higher phosphorus content:—T.C, 3.34; C.C, 0.34; Si, 2.48; Mn, 0.47; S, 0.091; and P, 1.22 per cent. In this case the range of heating was 17 to 850 deg. C., and the linear coefficients of expansion were 1.175 × 10^{-5} (17 to 400 deg. C.), 1.48 × 10^{-5} (575 to 850 deg. C.). This figure compares fairly well with personal tests.

Tests of iron expansion have all been done on annealed samples, as the usual course, because the castings as enamelled all have a corresponding heating in the burning of the ground coat, even if not previously annealed, and as the enamel only sets finally at round about 450 deg. C., the critical part of the iron expansion curve is that portion of the cooling curve where the enamel is set. There are variations in size at temperatures above the $\alpha\beta$ change points of the iron, but while these have an effect on the final dimensions of the test-piece, it is only the co-efficient which persists during the final cooling which affects the enamel.

The expansion curve of the enamel on the other hand shows an increasing co-efficient as the temperature rises, with a sharp increase just below the temperature at which the rod softens. This means, in the enamelling process, that at the moment when the enamel sets on the iron, it has a higher coefficient than the iron and consequently, on cooling, the enamel rapidly becomes in a state of tension. The later stages of cooling, however, show the enamel with a lower expansion than the iron, and if the adjustment of the enamel to the iron is correct, this later stage which would normally put the enamel in compression as regards the iron, just neutralises the tension arising from the earlier stage, leaving the iron-enamel junction sufficiently free from strain to be quite safe in use. It is probable that the enamel as actually adjusted finishes on the iron when cold under compression.

This theory of the behaviour of enamel coatings on iron agrees with all the known facts. It is well known, and under suitable conditions can be easily seen, that all enamels craze immediately on setting, and the crazes heal up again on further cooling. This behaviour is clearly in agreement with the results one would expect from consideration of the expansion curves.

It can be appreciated with very little consideration of these facts that there is enough difficulty in overcoming the inherent difficulties of the enamelling process without adding to them by trying to enamel castings with large variations of thickness which must produce differential stresses due to unequal heating and cooling.

As already explained, the expansion of the enamel in the lower part of its cooling range is less than the coefficient of the iron it fits to compensate for the higher expansion which always shows itself immediately after solidification, and as it is usual to do the actual measurement on the lower part of the curve, it is essential to maintain the enamel at a lower figure than the iron, usually 50 to 60 points lower.

Enamels for small articles usually have a smaller difference from the iron than bath enamels, and in addition, because of the short range of latitude of fit of the harder enamels, it is quite common nowadays to use a second enamel 15 to 20 points higher in expansion for the roll edges to minimise chipping. This practice has been more common in recent years also, because of the increase in use of square-topped baths, which are more prone to chipping at the roll corners than the older roll-edged types. The actual latitude required depends on the work to be done, and can be decided by the enameller for himself according to his results.

The author has to acknowledge the assistance of Mr. Deurvorst, of Ferro Enamelling Company, Holland, and of Mr. J. G. Pearce, of the B.C.I.R.A., and his staff, and Mr. T. Tyrie, of the Scottish Laboratories, in collecting some of the data used in writing this Paper, and also the kindness of Mr. Veilhaber for copies of his pamphlets and Papers.

TABLE I.—*Coefficient of Expansion Related to Composition.*

Iron No.	× 10^{-7} coeff.	T. C.	Gr.	C.C.	Si.	Mn.	S.	P.
1	363	3.50	3.43	0.07	2.19	0.50	0.082	0.98
2	358	3.24	2.77	0.47	2.33	0.70	0.109	1.33
3	361	3.50	2.96	0.54	2.42	0.40	0.065	1.25
4	359	3.40	3.10	0.30	2.69	0.43	0.110	1.00
5	369	3.39	3.06	0.33	2.80	0.51	0.095	0.82
6	370	3.65	3.07	0.58	2.42	0.42	0.069	1.12
7	371	3.22	2.57	0.66	1.96	0.32	0.126	1.47
8	373	3.70	3.38	0.32	2.00	0.46	0.122	0.41
9	379	3.56	2.89	0.67	2.33	0.76	0.049	1.01

TABLE II.—*Showing Coefficients of Expansion Related to Repeated Heatings.*

Range of heating.	Linear coefficients of expansion.
Deg. C.	
17–930	1.07 × 10^{-5} (17 — 227 deg. C.) 1.30 × 10^{-5} (227–600 deg. C.)
17–980	1.15 × 10^{-5} (17 — 340 deg. C.) 1.41 × 10^{-5} (340–600 deg. C.)
17–900	1.21 × 10^{-5} (17 — 423 deg. C.) 1.51 × 10^{-5} (423–600 deg. C.)
17–900	1.20 × 10^{-5} (17 — 400 deg. C.) 1.51 × 10^{-5} (400–600 deg. C.)

Light Castings need a *Fluid* Iron!

A free-running fluid iron is essential to produce clean, sharply-moulded light castings such as Rainwater pipes, Drain pipes, Builders' Hardware, Baths, Stoves, Gas and Electric Fires, etc. The relatively high phosphorus content of Rixon's (W'bro'.) No. 3 Foundry Iron ensures the necessary fluidity for this class of work.

Rixon's (W'bro'.) Irons are produced in two modern furnaces solely for the open market.

Fluidity Test

The illustration shows a typical spiral cast with a mixture containing Rixon's Iron. The feed to the spiral was only $\frac{3}{8}$-in. diameter.

ANALYSIS

	Per Cent
Silicon	3.29
Sulphur	0.025
Phosphorus	1.69
Manganese	0.34
Graphitic Carbon	3.52
Combined Carbon	0.12
Total Carbon	3.64

THE STANTON IRONWORKS COMPANY LIMITED
NEAR NOTTINGHAM

The largest producers of Pig Iron (for Sale) in Great Britain

RIXON'S (W'BRO') No. 3 Foundry Iron

The Week's News in Brief

Trade Talk

A DELEGATION from Sweden is to visit England shortly under the auspices of the Swedish Federation of Industries and Export Association, to discuss the question of furthering trade between the two countries.

A 23-TON CASTING for a hydraulic press to be used in boiler work has just been completed in the foundry of the John Thompson Engineering Company, Limited, Wolverhampton. This casting—a base plate—is 14 ft. by 9 ft. by 3 ft. 6 in., and is the largest yet made by the firm.

THE GENERAL ELECTRIC COMPANY, LIMITED, has announced that it will pay half their salaries to all married men who may be called up for active service in the event of a national emergency. For unmarried men 10 per cent. of salaries will be credited to their account and paid on their return.

THE FEDERATION OF BRITISH INDUSTRIES will be represented at the Paris Fair which opens on May 13 by a stand occupying a prominent site at the main entrance. At the week-end, from May 26 to May 29, a special visit will be paid to the Fair by members of the Association of British Chambers of Commerce and the Federation of British Industries.

GOLD MEDALS for 50 years' continuous service with Glenfield & Kennedy, Limited, Kilmarnock, were presented to three employees last week. They were H. Fulton (patternshop), C. Houston (light engineering department) and W. Watt (general engineering department). Mr. E. Bruce Ball, managing director, made the presentations and congratulated the men. Since the first gold medal was presented in 1930, 45 have been awarded.

FURTHER SHIPBUILDING ORDERS received during the past week include the following:—John Readhead & Sons, Limited, South Shields, order for a large cargo vessel; Smith's Dock Company, Limited, North Shields, four whaling boats; Furness Shipbuilding Company, Limited, Haverton Hill-on-Tees, two cargo vessels; Caledon Shipbuilding & Engineering Company, Limited, Dundee, two 10,000-ton passenger and cargo motor-vessels; Harland & Wolff, Limited, Govan, a 9,000-ton cargo motor-ship; A. & J. Inglis, Limited, Glasgow, paddle steamship for L.N.E.R. Humber ferry service; and Alex. Hall & Company, Limited, Aberdeen, tugboat for the Admiralty.

A SCHEME aiming at reducing steel workers' hours to 40 a week, is to be considered by a sub-committee representing the Iron and Steel Trades Confederation and the Iron and Steel Trades Employers' Association. Mr. W. Dodgson, Sheffield Divisional Officer of the Confederation, stated in an interview that the workmen's side believed a reduction in hours would be a valuable contribution to the unemployment problem and would be an economic proposition for employers. The representatives of the workmen's side had no desire to adopt a policy which would tend to cripple the industry or to injure it. On the contrary it was contended that the continuous operating of steel production departments would reveal advantages in several directions, but particularly in the direction of increased output and a reduction in the cost per ton of steel produced.

Company Reports

Peglers, Limited.—Dividend on the "A" and "B" ordinary shares of 23 1/13 per cent.

Herbert Morris, Limited.—Interim dividend on the ordinary shares of 7½ per cent., free of tax.

Park Gate Iron & Steel Company, Limited.—Dividend of 2½ per cent. for the year to March 31 last.

Babcock & Wilcox, Limited.—Final dividend on the ordinary shares of 6 per cent., plus a cash bonus of 2½ per cent., making 12½ per cent.

Hopkinsons, Limited.—Net profit for the year ended January 31, £224,165; brought in, £19,981; taxes, £80,000; ordinary dividend of 15 per cent.; transferred to reserve, £70,000; carried forward, £38,320.

Birmingham Small Arms Company, Limited.—Dividend for the six months ended January 31, 1939, on the 5 per cent. "A" cumulative preference stock and on the 6 per cent. "B" cumulative preference stock.

Personal

MR. W. DALLOW, whose retirement from the position as director and general manager of British Timken, Limited, Birmingham, we reported last week, has received a presentation from the workpeople, staff and directors.

MAJOR A. RHYDDERCH, who before his departure to Australia was associated with Hadfields, Lake & Elliott, and R. Hyde & Son, has established himself in business as Rhydderch Quality Castings, Queen Street, Alexandria, Sydney.

A COMPLIMENTARY DINNER was given at Glasgow last Thursday to Mr. John Craig, C.B.E., D.L., chairman of Colvilles, Limited, in recognition of his completing 50 years' service with the company. On behalf of the directors and staff, a bust of Mr. Craig by Epstein was presented to him, and Mrs. Craig received a diamond bracelet and a silver tea service.

MR. JEAN LOBSTEIN, who has been elected President of the French Foundry Technical Association, was born in Paris in 1890. He is a Chevalier of the Legion of Honour, and managing director of the Lobstein Foundry Company, which operates two foundries, one at Colombes (Seine) and the other at Argenteuil (Seine and Oise), making high-duty iron castings up to 15 tons in weight, as well as a variety of hot and cold pressings, boiler work, and a special type of electric iron. Mr. Lobstein is an enthusiastic supporter of industrial co-operative movements, whether economic, technical or social, and he is a Past-President of the Central Committee of Professional Associations; Federation of Engineering Employers; Federation of French Foundry Employers; Paris Foundry Employers' Federation. In addition he is a County Inspector of Technical Education, and a member of the Council of the French Employers' Federation. He is also a director of the Union des Industries Metallurgiques et Minieres.

MR. J. LOBSTEIN.

SIR WILLIAM BRAGG was presented with the John J. Carty medal and $3,000 (£600) for his work on X-rays and crystal analysis at the annual dinner of the National Academy of Sciences in Washington last week. Sir William Bragg, who is president of the Royal Society, director of the Davy-Faraday Research Laboratory, and a member of the Advisory Council for Scientific and Industrial Research, is now 76 years of age.

Wills

LOUIS, PROF. HENRY, of Newcastle-upon-Tyne	£16,932
RANSOME, E. C., of Ipswich, chairman of Ransomes, Sims & Jefferies, Limited	£64,914
BOLTON, E. R., chairman and managing director of Technical Research Works, Limited, London	£30,113

Allied Ironfounders (Ireland), Limited

We are glad to publish an official disclaimer of the paragraph on page 336 of our issue of April 20 concerning suspension of work by Allied Ironfounders (Ireland), Limited, at their factory at Waterford. Further, we express sincere apologies for the erroneous impression contained in that paragraph. We are officially informed that the company, in common with other foundries closely associated with the building trade's housing requirements, were experiencing a slack time, and so extended the normal Easter week-end holiday to include Easter week. Some departments continued to work normal time after the week-end holiday, and all other departments resumed on April 17, though on a short time basis. It is interesting to record that the company is showing a wide range of their products (including vitreous-enamelled goods) on Stand 164 at the Royal Dublin Show this week.

Company Meetings

General Refractories, Limited

SIR RONALD W. MATTHEWS (chairman), presiding at the annual meeting of General Refractories, Limited, held at Sheffield last week, said it was a matter of much regret that at his first annual meeting he should have to present accounts which showed that in 1938 the company had suffered a decided setback after several years of increasing prosperity. The trading profits for the year, including the amounts brought in by way of dividends from subsidiary companies, were £54,709, as compared with £117,700 for the previous year. The diminution in profits had been wholly brought about by reduction in turnover. In basic bricks alone the turnover had suffered a reduction of approximately 30 per cent., and similarly there was a reduction of approximately 10 per cent. in their turnover for iron foundry and general sands, and ganister. In the fire brick section, which was the one in which the largest output was attained, and the one in which the narrowest margin of profit appertained, there was a comparative fall in turnover of approximately 17 per cent. They believed, however, that they had at least maintained the same share of the available business which they enjoyed in 1937. With regard to the future, they must always be to a large extent dependent upon the steel industry, and in order to face more adequately a reduced demand for their products they were pushing on with their consolidation scheme. The board felt confident that this would ultimately produce such a reduction of charges as to ensure that trading profits in future would not suffer in the same proportion as they had done this year by reason of a large contraction in turnover. During the past year the board had been considering the question of reorganising the group with a view to effecting economies, increasing the efficiency in administration, and improving the financial structure. A scheme was eventually devised and adopted, but the major steps could not be taken before January 1, 1939. Apart from certain companies which, owing to the nature of their business, would continue to function as independent businesses, it had been decided to form three main groups—namely, a Scottish group, a South Wales group, and General Refractories, Limited. The whole scheme was now well in hand and should be completed at an early date. They had already been able to effect certain economies, but it would naturally take some time before they were able to reap the full benefits from the simplification of administration and closer control of the group's operations. He had no hesitation in stating that the position had already been materially strengthened by what had been done.

Contracts Open

Bristol, May 9.—Supply and erection of cast-iron economiser for use with an existing boiler having an economic rating of 80,000 lbs. per hr. of steam at a pressure of 200 lbs. per sq. in., for the Town Council. Mr. A. J. Newman, chief engineer, Electricity Department, Colston Avenue, Bristol, 1. (Fee £2 2s., returnable.)

Chapel-en-le-Frith, May 13.—Providing and laying about 1,200 yds. of 3 in., 4 in. and 6 in. dia. iron pipes, for the Rural District Council. Brady & Partington, engineers, Market Street, Chapel-en-le-Frith. (Fee £5, returnable.)

Forthcoming Events

MAY 4 AND 5.

Iron and Steel Institute:—Annual meeting at Institution of Civil Engineers, Great George Street, London, S.W.1, at 10 a.m. Annual dinner on May 4 at Grosvenor House Park Lane, at 7 p.m.

MAY 10.

Institute of Metals:—Annual May Lecture: "The Photographic Emulsion and Its Contribution to Science and Industry," by Dr. Olaf Bloch, at Institution of Mechanical Engineers, Storey's Gate, London, S.W.1, at 8 p.m.

MAY 20.

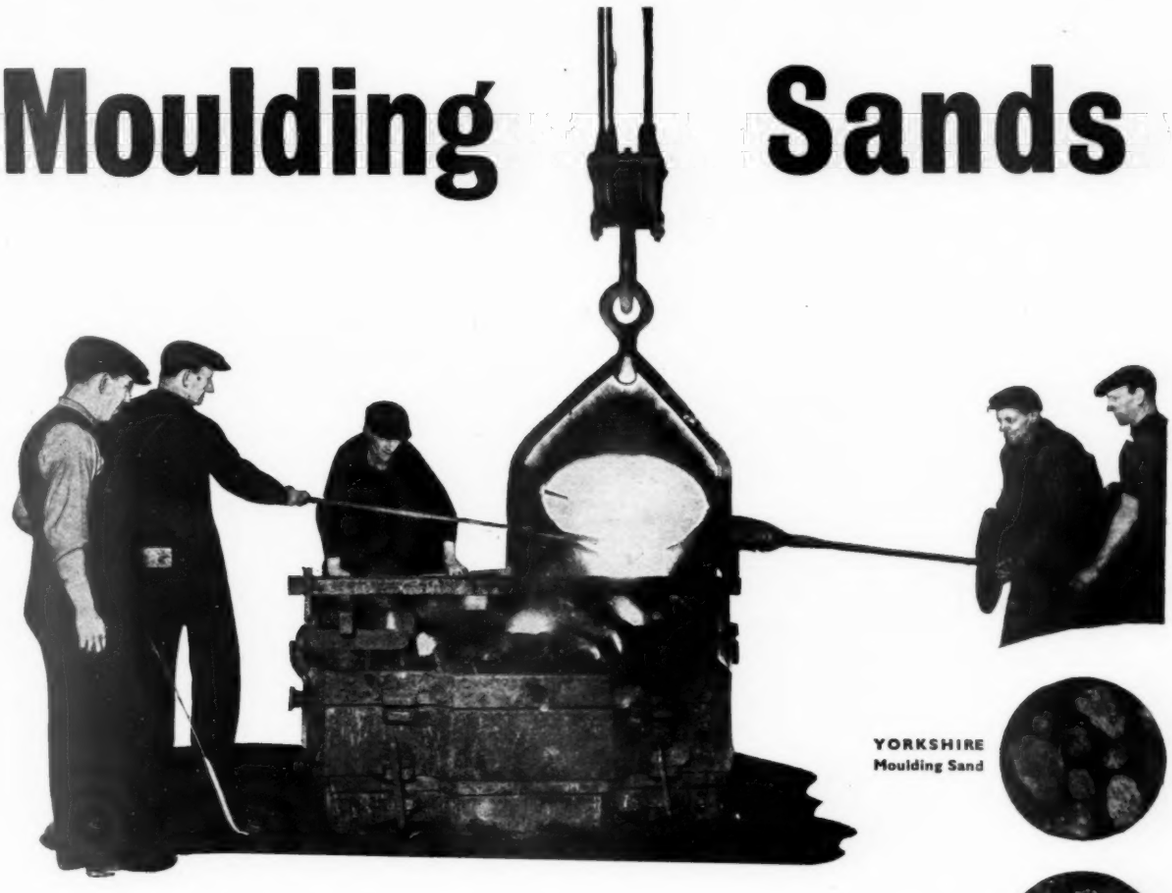
Manchester Association of Engineers:—Works visit to David Brown & Sons (Hudd.), Limited, Huddersfield, at 3 p.m.

The Institute of Vitreous Enamellers

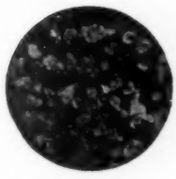
MAY 31—JUNE 2.

Joint Committee on Vitreous Enamelling (B.C.I.R.A. & I.V.E.):—Study course in Birmingham, including addresses and demonstrations. Open to members of both bodies.

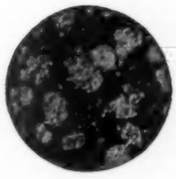
Moulding Sands



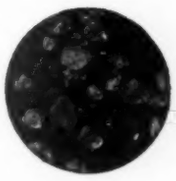
YORKSHIRE
Moulding Sand



THANET
Moulding Sand



YORK YELLOW
Moulding Sand



ZENITH
Moulding Sand

MANSFIELD
Moulding Sand

FROM unlimited resources we are able to supply Moulding Sands of various grades to meet all requirements. The photo-micrographs (magnified 25 diameters) on the right show five of the large variety of sands which we produce. Our Technical Staff is at your service and will be pleased to make recommendations and to assist you in the selection of the most suitable sand to meet your exact needs.

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GENERAL REFRACTORIES Ltd.

Telephone : *Sheffield* 31113 (6 *lines*). **GENEFAX HOUSE, SHEFFIELD, 10** *Telegrams :* "*Genefax, Sheffield.*"

Raw Material Markets

Orders for iron and steel for Government departments have reached such proportions that many producers are having to neglect commercial work to some extent. The fact, therefore, that the amount of civil business available at the present time is still rather low, is less obvious than it might be.

Pig-Iron

MIDDLESBROUGH.—The demand for iron from the local foundries continues to be restricted and the current production of around 1,000 tons per week is ample to meet all requirements without delay. In addition, most makers have quite substantial stocks behind them. For delivery in the Middlesbrough and Falkirk areas, No. 3 Cleveland G.M.B. foundry iron is quoted at 99s., No. 1 foundry 102s., and No. 4 foundry and No. 4 forge 98s., all less 5s. per ton rebate.

The hematite section of the market continues to become more and more active, and consumers are calling for deliveries under contracts more freely. As yet, the amount of new contracting done has not reached very substantial proportions, but there should shortly be an increase, as many existing commitments will expire. A large part of the make is being consumed by producers' plants. Deliveries to Sheffield are now more satisfactory.

LANCASHIRE.—With business becoming rather more satisfactory, the outlook in this area is definitely brighter. During the past week or two there has been quite a good number of consumers in the market willing to buy forward. Makers, of course, have welcomed this opportunity, which has been denied them for a long time past, and some fair business has resulted. Certain users have booked supplies for delivery up to the end of the year, although most of the orders have been for deliveries during the next few months. Existing contracts, too, are being worked off at a faster rate. An improvement is noticeable in the condition of many jobbing founders, while the specialised engineers are still working to capacity. Textile-machinery makers are still only working intermittently, while light-castings founders could do with much more work.

MIDLANDS.—It is some time since it has been possible to record an improvement in business in high-phosphorus iron, but there has certainly been more activity during the past few days, some consumers having entered into forward contracts as a precaution against political eventualities. Unfortunately, it cannot be said that there has been any real change in the consumption of iron, which remains disappointing. The main consumer, the light-castings trade, should now be better employed, as, according to the most recent returns of the building trade, that industry has become much more active of late, but there has been little indication of a real improvement among light-castings makers, and many works are still on short time. On the other hand, consumers of low-phosphorus iron are busy and are placing large orders for iron in order to safeguard their future needs. Hematite, too, is being taken up in heavier tonnages, and the turnover is quite satisfactory.

SCOTLAND.—The recent improvement in this area has been maintained, although the demand for iron remains rather poor. Some concerns which are dealing with Government work are covering ahead, but there has not been much business done beyond the end of the first half of the year. No. 1 foundry iron is quoted at 108s., and No. 3 at 105s. 6d., both f.o.t. furnaces. Most of the local steelworks are well contracted ahead for supplies of basic and hematite, but there is a moderate amount of business about and consumption is on a satisfactory scale. Hematite mixed numbers are quoted at 120s. 6d. and basic at 92s. 6d., both less 5s. rebate, delivered works.

Coke

A firm tone rules on the foundry-coke market, and most of the producers are well sold ahead. The minimum price for both Durham and Welsh coke is 50s. 6d. per ton, delivered Birmingham and Black Country stations, and this quotation will remain in operation at least up to the end of June.

Steel

Nearly all sections of the steel market remain very strong and producers are active. It is understood that the British Iron & Steel Corporation has bought a tonnage of sheet bars in Australia in order to relieve the heavy demand that exists at home. In some cases, makers of sheets have complained that the shortage of raw material is keeping down their outputs. Armament orders are generally sufficient to maintain full-time working at the steel plants, but there has recently been an increase in the amount of commercial business placed, not all of which can be accepted for any definite date of delivery.

Scrap

Visible supplies of iron and steel scrap are practically all accounted for, and there has been little change in the position during the past week. Merchants are adhering to the fixed schedule prices. Steelworks are handicapped by their inability to obtain adequate supplies, and are hoping that substantial tonnages will shortly be imported. Sellers are unwilling to enter into long-term contracts, owing to the uncertainty of the future, but consumers would willingly buy well ahead if they were given the opportunity.

Metals

Non-ferrous metals have been remarkably firm during the past week, considering that there have been at least three events which in the past would have rocked the markets to their foundations. In the first place, a Budget such as the one presented to the House by Sir John Simon recently would certainly have undermined the confidence of commodities. Secondly, the introduction of conscription in peace-time would have had a disturbing effect on business, while a political oration such as the one delivered to the Reichstag by Herr Hitler might well have been expected to have had violent repercussions. But all these events have been taken quite calmly, which is characteristic of the change which has come over the commodity markets during recent months.

Copper.—This market has been quite firm, despite the fact that there has not been any notable support from consumers. Since our last report, the price of copper in the United States has been increased to 10¼ cents a lb., or 10½ cents in the case of the Phelps Dodge Corporation. This increase follows a series of decreases. It is reported from New York that domestic copper sales on Wednesday of last week totalled 29,238,000 lbs., as against 3,498,000 lbs. on the previous day and only 1,844,000 lbs. on the day before that. The turnover on Wednesday was the highest since July, 1938, and was due to consumers endeavouring to cover ahead at the low prices. An indication of the small amount of business done by the American copper industry last year is shown by the annual report of the Cerro de Pasco concern; the net profit of the company was little more than one-third of the previous year's level.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £42 6s. 3d. to £42 8s. 9d.; Friday, £42 6s. 3d. to £42 8s. 9d.; Monday, £41 16s. 3d. to £41 18s. 9d.; Tuesday, £41 10s. to £41 12s. 6d.; Wednesday, £41 13s. 9d. to £41 15s.

Three Months.—Thursday, £42 13s. 9d. to £42 15s.; Friday, £42 13s. 9d. to £42 15s.; Monday, £42 2s. 6d. to £42 5s.; Tuesday, £41 17s. 6d. to £41 18s. 9d.; Wednesday, £42 to £42 1s. 3d.

Tin.—At a meeting of the International Tin Committee at The Hague on Thursday last, it was decided to maintain the existing export quota for the next quarter, *viz.*, 40 per cent. of standard tonnages. The official statement issued after the meeting contained no details of the measures taken to eliminate over-exports. It is generally believed that the reasons for this were that the accumulated over-exports at the end of March were considerably lower than at the end of the preceding months, while further details of future American tin purchases are awaited. It is learned in authoritative circles that the United States Government has made no specific proposals to the British Government with regard to the projected barter plan which would entail the exchange of American cotton and wheat for British, Dutch and Belgian tin and rubber. The next meeting of the Committee will be held in Paris on June 14. During the past week or two there has been rather less demand from American consumers for European tin; business in this country is on a moderately good scale, and prices reached a new peak from October, 1937, on Monday.

According to the April Statistical Bulletin of the International Tin Research and Development Council (Statistical Office, 21, Prinsessegracht, The Hague, price 1s.), world tin production in the first two months of 1939 amounted to 26,000 tons, being a decrease of 4 per cent. as compared with 1938. World apparent consumption in the first two months of the year amounted to 22,100 tons, which represents a decrease of 17 per cent. as compared with 1938. Consumption in the United Kingdom, at 3,015 tons, showed an increase of nearly 600 tons. World tinplate production in the first two months amounted to 573,000 tons, against 503,000 tons in 1938.

Mr. W. H. Gartsen (Henry Rogers, Sons & Company) states that the total visible supply of tin on April 30 was 25,574 tons, against 25,314 tons on March 31. The carry-over in the Straits Settlements was 5,042 tons (5,680 on March 31), while the carry-over at the Arnhem (Holland) smelter was 1,871 (1,735) tons.

Official quotations were as follows :—

Cash.—Thursday, £224 5s. to £224 15s.; Friday, £223 15s. to £224; Monday, £225 5s. to £225 10s.; Tuesday, £224 15s. to £225 5s.; Wednesday, £225 5s. to £225 10s.

Three Months.—Thursday, £222 to £222 5s.; Friday, £221 5s. to £221 10s.; Monday, £223 to £223 5s.; Tuesday, £222 10s. to £222 15s.; Wednesday, £222 15s. to £223.

Spelter.—There has been a fairly good demand for this metal of late, and the galvanisers have been especially active in this respect in connection with their requirements for air-raid shelters. Support from the Continent continues to be on the quiet side.

Daily market prices :—

Ordinary.—Thursday, £13 15s.; Friday, £13 15s.; Monday, £13 10s.; Tuesday, £13 7s. 6d.; Wednesday, £13 10s.

Lead.—Consumption of this metal is believed to be satisfactory, although new business does not involve substantial tonnages. In the aggregate, however, business is moderately good. When the outlook becomes a little clearer, it is expected that consumers will have more confidence and cover their forward requirements.

Day-to-day quotations :—

Soft Foreign (Prompt).—Thursday, £14 12s. 6d.; Friday, £14 17s. 6d.; Monday, £14 8s. 9d.; Tuesday, £14 7s. 6d.; Wednesday, £14 7s. 6d.

Scrap.—There has been an improved demand for scrap material, and there is a distinct shortage of certain descriptions.

Approximate selling prices for old metal :—New aluminium cuttings, £70; rolled, £57; cast, £32; foil, £80. Copper, £38 to £44; braziery, £35 to £37. Brass (clean), £20 to £24. Zinc, £10. Lead, £13 10s. Gunmetal, £38 to £39.

Catalogues Received

Electric Hardening Furnaces. A novel and extremely efficient device is disclosed in a leaflet (data sheet No. 843) received from Birmingham Electric Furnaces, Limited, Tyburn Road, Erdington, Birmingham. It has been designated a "pan dumper" and is incorporated in a rotatable electric furnace. It consists of a series of pivoted pans. These "pans" register with either of two doors and with discharges to either oil or water. The atmosphere is controlled to eliminate scaling, whilst obviously temperature is easily regulatable. The automatic dumping certainly makes for foolproof control.

Diesel Engines. Blackstone & Company, Limited, of Stamford, have sent us two folders (901 B.B. and 902 B.B.) both dealing with the Blackstone-Brush horizontal opposed-cylinder type, ranging in power from 85 to 2,400 h.p.

MR. A. S. BEECH was the lecturer last Monday at a meeting of the South African Branch of the Institute of British Foundrymen, held in Johannesburg.